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ABSTRACT

This final report details the outcomes of a 3-year project involving children with severe disabilities (ages birth-6) designed to: (1) determine the effectiveness of specific therapeutic intervention techniques on the development of basic motor skills in young children with severe and multiple disabilities; (2) explore the relationship between specific motor skills and the development of other associated motor skills; and (3) determine the effectiveness of "packages" of therapeutic intervention techniques on the development of basic motor skills. Individual studies investigated using vibration, vestibular stimulation, and inversion techniques. Results found in the six studies utilizing vibration, that 8 of 18 subjects (ages 1-6) with severe and multiple disabilities demonstrated an increase in head erection or sitting. In the five studies that used vestibular stimulation, 8 of 10 children in the head erect studies and 6 of 7 children in the sitting studies showed an increase in ability. The results in two studies involving eight children and utilizing inversion suggest that the static method may be more effective for increasing head erect behavior than a dynamic method of inversion. A final study involving two children found vestibular stimulation may be a potential antecedent stimulus for a variety of motor programs. (Contains 93 references.) (CR)

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ED 408 793

Final Report

Developing Basic Motor Skills in Infants and Children with Severe Handicaps: An Experimental Analysis with Implications for Education and Treatment

Jane Rues
Debbie Cook
Doug Guess

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FINAL REPORT

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Co-Investigator: Jane Rues, Ed.D., OTR - Dr. Rues coordinated the administrative responsibilities, prepared progress reports and manuscripts. She contributed to data analysis and dissemination of findings.

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STATEMENT OF PROBLEM

The term "cerebral palsy" refers to a large group of movement disorders of varying symptoms and severity. A child with severe cerebral palsy may be mentally retarded and/or subject to seizures, as well as physically handicapped. Some major causes of cerebral palsy can now be eliminated (e.g., rubella, several types of mother-based blood disorders). Nevertheless, the United Cerebral Palsy Association (1983) reports that between one and three infants out of every thousand liveborn develop cerebral palsy--about 12,000 new cases per year. Even though the technology of prevention is improving, the number of new cases each year has not decreased. This is apparently due to breakthroughs in new intensive care technologies, which allow many premature or very frail infants to survive, but not necessarily without some damage to the central nervous system. Indeed, one recent study (Dale & Stanley, 1980) reported that decreasing Australia coincided with an increased incidence of spastic cerebral palsy in these infants. In short, despite important medica breakthroughs, cerebral apsly is likely to remain a serious handicapping condition.

The child with severe cerebral palsy will usually begin to show serious developmental delays during the first year of life. In contrast to the nonhandicapped infant, who gradually gains increased control over body movements and the external environment, the child with cerebral palsy has difficulty mastering even basic motor skills such as holding his or her head erect, sitting, etc. Although different therapeutic techniques have been proposed and utilized by occupational and physical therapists to improve motor behavior, very little scientific evidence exists attesting to their effectiveness or the parameters governing it.

This research proposal was designed to (1) experimentally determine the effectiveness of specific therapeutic intervention techniques on the development of basic motor skills in young children with severe and multiple handicaps; (2) to explore the relationship between specific motor skills and the development of other associated motor skills; and (3) to experimentally determine the effectiveness of "packages" of therapeutic intervention techniques on the development of basic motor skills.

In this period of extreme cost-accountability the proposed type of research was even more imperative. The use of inefficient or ineffective therapies cannot be tolerated. The less we impact the development of severely impaired children, the more dependent they are likely to be throughout their entire lives. Not only is this an extreme personal tragey for these individuals, but it represents a tremendous long-term drain on the resources of an already hard-pressed social support system. Early intervention can potentially reduce both the personal and social costs by making these people less dependent, but only if it is optimally effective. It is within this context that the significance of this research should be viewed.

LITERATURE REVIEW

Overview

Treatment procedures currently employed by occupational and physical therapists are based on the principle that new desired movement patterns can be learned by clients only if abnormal muscle activity is reduced. In other words, the therapeutic techniques are designed to provide stimulus situations which tend to restore balance between facilitory and inhibitory neural mechanisms operating at all levels of the neural axis (Bishop, 1975). These therapeutic techniques, developed from neurophysiological principles, can be viewed simultaneously as antecedent stimuli for certain motor behaviors. Therapeutic techniques such as vibration vestibular system and inversion are used (and abused) daily in clinics, classrooms and other programs for children with severe motoric handicaps. The potential power of these techniques and the differential effects across handicapping conditions and ages requires systematic investigation. Applied research on the acquisition, generalization, and maintenance of critical motor behaviors will provide a data base for the individual analysis of these techniques and subsequent combinations of interventions.

To date there have been few carefully controlled studies to determine the actual effectiveness of these treaments or combination of treatments is superior to any other (NIH Publication No. 81-159, 1980). In noting this situation, Takata and Keilhofner (1980) pointed out "the critical need for research that contributes to client improvement...and that conceptualizes the treatment process as a research model" (p. 253). They added that "as an applied field...therapy is most in need of applied research" (p. 258). The Division of Maternal and Child Health recognizing the problematic issue this poses recently funded a 2 year continuing education program with the goal to train therapists in single subject research design.

There are several reasons for the lack of research on the effects of treatment with motorically impaired children. Three of these summarized in a report by the National Institute of Neurological and Communicative Disorders and Stroke (NIH Publication No. 81-159, 1980) are: (1) that such studies require the careful matching of patient groups by age, symptoms, and so on--a requirement difficult to achieve in a disorder as varied and complex in symptoms as cerebral palsy; (2) traditional control group experimental studies might entail withholding treatment from one group of patients, which would be undesirable as well as unethical; (3) there have been no objective measurements or scales of motor performance in cerebral palsy patients which could be used to assess progress or change resulting from treatment.

This research program was designed to transcend the three problems cited in the N.I.N.C.D.S. report. The first two problems--the heterogeneity of the targeted population and problems of control groups--can be avoided by utilizing single subject research designs in which individual subjects serve as their own experimental controls. These designs, when utilized appropriately, meet all scientific criteria for the establishment of causality (Hersen & Barlow, 1976). They represent the only know experimentally sound strategy for dealing with the first two problems cited above (Martin & Epstein, 1976). The third problem--the lack of objective, precise measurements of motor behavior that can be used to assess progress and change--was solved by utilizing the quantitative measurement system developed by the investigators and their colleagues. These procedures are summarized in the 'Progress to Date' section of the review. Following are comprehensive literature reviews for the three therapeutic techniques investigated. These were continuously updated and revised over the course of our research.

Vibration

Vibration's effect as a neurophysiological facilitator has resulted in its recommended use as a potential therapeutic tool (Bishop, 1974, 1975a, 1975b; Johnson, Bishop & Coffey, 1970; Koozwara, 1975). Vibration used for therapeutic purposes is a high frequency, low amplitude vibratory stimulis applied directly and locally to a specific muscle or tendon.

The purpose of this review is to summarize the available body of knowledge relating to the effects of vibration of human skeletal muscles. This review addresses two broad categories. First, the response to vibration in nonhandicapped adults and laboratory animals is presented, followed by a review related to the response to vibration of adults and children with neurological impairments.

Motor Effects of Vibration

Bishop (1974) described the three major motor effects of vibration as activation of muscle contraction, depressed excitability of antagonistic muscles via reciprocal inhibition, and suppression of monosynaptic stretch reflexes in the vibrated muscle during vibration. A discussion of these major effects follows.

Activation of Muscle

The normal response of a skeletal muscle to mechanical vibration was slow reflex contraction known as the tonic vibratory reflex (TVR) (de Gail, Lance, & Neilson, 1966; Eklund & Hagbarth, 1966). The TVR simulated the static fusimotor activation of primary endings of the muscle spindle that normally occurred in isometric voluntary muscle contractions. Repetitive discharges from Ia afferents from vibrated muscle were transmitted monosynaptically to homonymous motorneurons driving them into repetitive discharge (Matthews, 1966).

Activation of the TVR appeared to involve supraspinal structures, multiple synapses, and gamma as well as alpha motor neuron activity (Bishop, 1974; de Gail et al., 1966).

Numerous studies have described the muscle activating effect of vibration (Eklund & Hagbarth, 1966; Hagbarth & Eklund, 1966a; de Gail et al., 1966; Lance, de Gail, & Neilson, 1966). It has been generally accepted that vibration, applied as a high frequency, low amplitude stimulus, selectively activated primary endings of the muscle spindle and subsequently activated the alpha motor neuron through the fusimotor system (Bishop, 1975a; Eklund & Hagbarth, 1966; Hagbarth & Eklund, 1969). Gillies, Lance, Neilson, and Tassinari (1969) applied vibration to the tendons of cats and determined that the physiological effects were the result of repetitive stimulation of primary spindle endings and activation of group Ia afferent fibers. However, Burke, Hagbarth, Lofstedt, and Willin (1976), in a study of human adult subjects, determined that primary and secondary endings as well as Golgi Tendon organs, responded to vibration in relaxed muscle. There was a wide range of responsiveness to vibration within each group of receptors and significant overlap between groups of receptors. The study concluded that vibration to a relaxed muscle was not a specific stimulus for Ia endings, although primary endings were generally driven at higher rates than secondary endings.

Reciprocal Inhibition

The second motor effect of the TVR was the depressed excitability of the antagonistic muscle. Inhibition of the antagonist muscle was thought to be the result of reciprocal innervation. Two investigators (Eklund & Hagbarth, 1966; Hagbarth & Eklund, 1966a) determined that vibration of the tendon caused a gradual increase of its muscle's activity accompanied by a decrease of activity in the antagonist muscle. Bishop (1974) described the effect of vibration when applied to antagonistic muscles. Both muscles developed strong tension when vibrated singly. If vibration was then applied simultaneously to the two muscles, neither muscle contracted. Each muscle canceled out the other's facilitatory effect at its motoneuron pool (Lance et al., 1966).

In another study, Marsden, Meadows, and Hodgson (1969) were able to inhibit vibration-induced clonic contraction of the gastrocnemius muscle by simultaneous vibration of the tibialis anterior muscle. An exception to the above findings was noted in a study of the TVR in the masseter muscle (Godaux & Desmedt, 1975). When the masseter tendon was vibrated, no inhibition of antagonists was elicited.

Suppression of the Monosynaptic Phasic Reflex

It has been found that tendon jerks and phasic stretch reflexes were completely suppressed or greatly diminished during muscle vibration (de Gail et al., 1966; Hagbarth & Eklund, 1966a; Lance et al., 1966). As vibration stimulated the TVR, the phasic stretch reflex of the same motoneuron pool was inhibited (de Gail et al., 1966). This phenomenon was known as "vibration paradox" (Desmedt, 1983, p. 671). The paradox made it possible to avoid phasic, involuntary motor responses while using vibratory stimulation to investigate a sustained inflow from the stretch receptors similar to voluntary muscle contractions (Hagbarth, 1973).

It was not necessary to elicit a TVR to suppress phasic reflexes using vibration (Arcangel et al., 1971; de Gail et al., 1966). De Gail et al. (1966) found that during vibration of the patellar tendon in nonhandicapped adults, knee jerks elicited at five second intervals were depressed whether a TVR of the quadriceps muscle was present or absent. Arcangel et al. (1971) studied the responses of the Achilles tendon reflex and H-responses (muscle contractions elicited by direct electrical stimulation to the efferent neuron) to vibration in nonhandicapped adults. The effect of vibration at 53 cycles per second depressed both phasic reflexes (the Achilles tendon reflex) and the H-response. It was not necessary to elicit an active TVR to depress either the H-response or the Achilles tendon reflex.

Godaux and Desmedt (1975) in a study of the human masseter muscle in 17 nonhandicapped adults, found no such vibratory paradox. The TVR was elicited using vibration of the mandible at midline. Phasic reflexes were elicited by electromechanical hammers and the H-response was elicited by electrical stimulation to the masseter nerve. Jaw vibration did not depress the masseter reflex or the H-response in the masseter muscle.

The cause of the vibration paradox response and suppression of the H-reflex has been explained in two ways. Hagbarth (1973) described the phasic reflex suppression as the result of many primary endings so occupied by the vibratory stimulus that they were unavailable to respond to the fast stretch--the "busy line" phenomenon (p. 430). The second explanation for suppression of phasic stretch reflexes and suppressed H-responses during vibration was spinal presynaptic inhibition of the monosynaptic pathway (Lance, Neilson, & Tassinari, 1967; Gillies et al., 1969).

Variables Influencing the Strength of the TVR

The tonic vibratory reflex has been elicited in every human muscle except the facial and tongue muscles, and has been produced in people of all ages (Eklund & Hagbarth, 1966). The strength of the TVR response is highly individual. However, in a given individual, the response is highly reproducible over trials and over time (Eklund & Hagbarth, 1966).

The characteristics of the vibrator itself and the way in which it is applied to the muscle have direct effects on the resulting afferent inputs. The major specific inputs are frequency, amplitude, and location of the vibratory stimulus. Other influences that effect the strength of the TVR are muscle length, the state of muscle contraction, timing of the stimulus and the central state of the subject. The major inputs are discussed first.

Frequency and amplitude. The frequency and amplitude of the vibratory thrusts applied to muscle effects the activation and strength of the TVR. Eklund and Hagbarth (1966) tested vibratory frequencies from 20 to 200 cycles per second in 100 nonhandicapped subjects. They found, that when using vibration amplitudes of 0.6 to 1.8 mm, the rising phase of the TVR was more rapid and the response was stronger with the higher frequencies of vibration. Amplitudes of 3.3 mm caused intolerable discomfort to most subjects. Eklund and Hagbarth concluded that frequency of vibration was the main determinant of the TVR strength, with increased frequency producing improved strength in nonhandicapped adults.

Johnston, Bishop, and Coffey (1970) used six nonhandicapped adults to study the strength of the TVR in the biceps brachaii muscle. A sharp rise in tension was noticed within the first second of vibration, followed by a slower rise to a plateau with a rise time of about 20 seconds. When vibration ceased, the muscle quickly relaxed. For some subjects, relaxation was more gradual, often occurring in steps.

Hagbarth and Eklund (1969) contended that very high amplitude, low frequency vibration could elicit responses from Golgi tendon organs and secondary endings resulting in inhibitory influences and decreased TVR responses.

Homma, Kobayashi, and Watanabe (1970), in a study of cats, describe a "preferred frequency" of discharge above which a motoneuron could not fire in response to increased bombardment of Ia fibers. Preferred parameters of vibration in nonhandicapped subjects were generally accepted as a frequency of 100 to 200 cycles per second, and an amplitude of 0.5 to 1.5 mm (Eklund & Hagbarth, 1966; Hagbarth, 1973).

Location of the vibrator. According to Brown, Engberg, and Matthews (1967), in studies of the cat soleus muscle, vibration was most effective when applied longitudinally at the soleus tendon. In man it was not possible to apply the stimulus in this way. Generally speaking, no matter whether the vibrator covered a large contact surface over the muscle belly (de Gail et al., 1966) or a smaller contact surface over the tendon (Eklund & Hagbarth, 1966), the TVR could be elicited. However, vibration to muscle bellies was less efficient (Hagbarth & Eklund, 1966a).

Marsden et al. (1969) were able to increase muscle tension when vibrating the human Achilles tendon by applying a second vibrator over the muscle belly. They postulated that the tendon vibration did not activate all the muscle spindles.

The TVR could be produced by vibrating bone. In studies of the masseter muscle (Desmedt & Godaux, 1975; Godaux & Desmedt, 197), a wave of excitation was elicited in the masseter muscle by applying vibration to the mandible at midline.

As noted earlier in this review, normal responses to vibration were highly individual. Responses in nonhandicapped subjects were dependent on the above parameters of the vibratory stimulus as well as the variables that effect changes in sensory inflow. These variables were muscle length, the state of the contraction, timing of the stimulus, and the central state of the subject. Their effects caused secondary changes in sensory inflow that altered the response to vibration.

Variation in muscle length and state of contraction. In a passively shortened muscle, the efficiency of the vibratory stimulus increased with passive enlongation of the muscle (Burke, Andrews, & Lance, 1972; Eklund & Hagbarth, 1966; Johnson et al., 1970). In a study by Burke et al. (1972), vibration did not significantly alter the force of a maximal voluntary contraction. However, when the relaxed muscle was free to shorten against gravity, the isotonic state, a slow joint movement occurred as more motor units were recruited (Lance et al., 1966). Hagbarth (1973) found that it took 15 to 30 seconds of vibration before a steady contraction was produced in the quadriceps muscle. If the muscle was then loaded so that stretch or lengthening occurred, the contraction immediately increased like a load compensated response (Hagbarth & Eklund, 1966a). The motor effect declined slowly when vibration was suddenly withdrawn. Eklund and Hagbarth (1966) found that the tension built in the muscle was less dependent on muscle length when the subject elicited a weak voluntary contraction.

Timing of the vibratory stimulus. The TVR was influenced by the state of muscle contraction before, during, and after vibration was applied.

Post vibratory potential. In both isometric and isontonic states, Eklund and Hagbarth (1966) found that when vibration and voluntary contraction ceased, electromyographic activity persisted. These periods of residual facilitation lasted 20 to 30 seconds after isotonic contractions and 1 to 2 minutes after isometric contractions.

In a study of the effect of voluntary control on vibration-induced reflex responses, Marsden et al. (1969) found that a previous period of vibration enhanced a subsequent period of vibration. This post vibration potentiation was strongest when the subsequent vibratory stimulus was applied 5 seconds after cessation of the initial period of vibration. No potentiation was recorded when the second vibratory stimulus was applied 5 minutes later. Muscle contractions near maximal voluntary effort were developed when vibration was given in short, repeated bursts. Potentiation persisted with voluntary inhibition of the contracted muscle, but when the subject voluntarily maintained the contraction after vibration ceased, no potentiation occurred. The authors hypothesized that potentiation depended on muscle relaxation between stimuli.

Hagbarth and Eklund (1969) found that the TVR was greatly enhanced when elicited immediately following a strong voluntary isometric contraction of 1 to 2 minutes.

Reliability of the TVR response over time. It was generally accepted that the TVR could be reproduced in a given subject on successive trials (Johnston et al., 1970; Goldfinger & Schoon, 1978). Johnston et al. (1970) found that the rise time and plateau tension of the biceps brachaii muscle was reproducible on successive trials. Typically, there was a sharp rise in tension within the first second of vibration followed by a slower rise toward the plateau tension. The average rise time to the plateau in six nonhandicapped subjects was 20 seconds. Goldfinger and Schoon (1978) produced high intraday reliability (0.85) in a study of vibration of the Achilles tendon in 30 nonhandicapped young adults.

Variables in central state. Numerous studies have been carried out to measure the effect of vibration using variables of central state. These include reinforcement maneuvers, voluntary effort, changes in perceived movement and position, postural and vestibular influences, protective reflexes, and temperature.

Reinforcement maneuvers. The effects of reinforcement, for example the Jendrassik maneuver (the subject interlocks the fingers and pulls outward with maximum force) and ear twisting, may be facilitory to the TVR, however, the effect varies from subject to subject and is not always reproducible (Burke et al., 1972; Eklund & Hagbarth, 1966; Lance et al., 1966). Burke et al. (1972) studied reinforcement performed before, during, or throughout vibration, and at different joint positions. The results indicated that the TVR was potentiated most by the Jendrassik maneuver when the muscle was in a shortened position, and that there was little variation from one joint position to another.

In nonhandicapped subjects, Johnston et al. (1970) found that contracting the opposite hand during vibration of the biceps brachaii muscle augmented the response of the TVR.

Marsden et al. (1969) used fist clenching and teeth clenching for 5 to 10 seconds prior to vibration to study the effect of reinforcement. The subsequent response was increased muscle contraction of 100 to 150 percent.

By contrast, a 1976 study by Burke and Schiller in which the effects of vibration were measured as single motor unit discharges, indicated that no change occurred in the potentials with attention or reinforcement maneuvers.

Voluntary effort. There was evidence that vibration had no effect on maximum voluntary power and that the TVR could be controlled by voluntary effort in nonhandicapped subjects (Burke et al., 1972; Eklund & Hagbarth, 1966; Hagbarth & Eklund, 1966a; Marsden et al., 1969).

Marsden et al. (1969) studied the effect of voluntary effort on vibration-induced tonic muscle contraction. The results indicated that the contraction could be stopped at any time by conscious effort, but returned when the subject's attention was diverted. During sleep, no tonic contraction was elicited. The authors attributed this lack of response to gamma motoneuron depression. When awake, gamma efferent stimulation increased the sensitivity of Ia afferents resulting in an increased TVR. Voluntary effort combined with vibration increased the gamma bias of the muscle spindles to strengthen the TVR (Hagbarth & Eklund, 1969).

Changes in perceived movement and position with vibration. The muscle spindles played no part in the conscious perception of vibration (Gillies et al., 1969), but instead, perception took place at supraspinal centers (Hagbarth, 1973). De Gail et al. (1966) found that the TVR in cats was abolished by spinal transection, which removed facilitory influences from the reticular spinal and vestibulospinal pathways. This finding supported the work of Hagbarth and Eklund (1969), who found that muscle spindle endings required continuous central support to respond effectively to sustained muscle stretch. No TVR was producible in denervated muscle (Bishop, 1974).

Hagbarth (1973) described changes of central excitability induced by vibration in which the subjects had no sense of effort. Voluntary joint movement in one direction was enhanced by vibration, while the opposite movement was sensed as being resisted. This phenomenon occurred in both sustained voluntary contraction and in fast alternating contractions (Hagbarth & Eklund, 1966a; Eklund & Hagbarth, 1966). These effects were elicited primarily in antigravity muscles. In contrast, the muscles that were controlled visually and tactually were minimally affected by vibration of the prime movers.

The direction of movement was usually correctly perceived by the subject during vibration. However, during an isometric contraction, vibration could induce a sense of slow joint position changes in some subjects (Hagbarth & Eklund, 1966a; Goldfinger & Schoon, 1978). The subjects may not have perceived the correct extent of vibration-induced position or movement. This underestimate of the true muscle shortening may have resulted from central misinterpretation that the muscle spindle was being discharged due to stretch or loading of the muscle rather than by the vibratory stimulus (Hagbarth, 1973).

Postural and vestibular influences. The position of the body and head influenced the strength of the TVR in nonhandicapped adults (Bishop, 1974; Curry & Clelland, 1981; Eklund & Hagbarth, 1966). In a study of nonhandicapped adults, Hagbarth and Eklund (1966) found that body position facilitated the TVR in extensor muscles from the supine position and in flexor muscles from the prone position. In supine lying, extension of the head was facilitory to the TVR in the quadriceps, while flexion of the head was inhibitory to the same TVR. Also, in supine, when the quadriceps were vibrated simultaneously, knee extension occurred more rapidly and with greater strength on the side toward which the head was rotated.

The findings of Curry and Clelland (1981) using upper extremity vibration with head turning, paralleled those of the lower extremities previously discussed. When wrist extensor muscles were vibrated during voluntary isometric contractions, active head rotation to the same side as the contracting muscle enhanced its TVR. The authors concluded that the combined influence of voluntary effort, vibration and the asymmetrical tonic neck reflex produced the stronger effect by increasing the afferent input to the motoneuron pool.

Heiniger and Randolph (1981) advocated applying vibration in the tonic labyrinthine inverted position to a contracting, stretched muscle, to obtain the best therapeutic response.

Another vestibular influence on the TVR, caloric stimulation, enhanced the strength of the TVR in a study by Eklund and Hagbarth (1966). An injection of cold air to the right ear of the subject produced a stronger TVR in the left quadriceps muscles.

Protective reflexes. A quick withdrawal response to vibration in some subjects was described by Hagbarth and Eklund (1969). The protective reflex movements resulted from the vibratory stimulus being perceived as a noxious stimulus.

Temperature. Cooling of the subject increased the strength of the TVR. Warming produced a suppression of the vibration reflex (Eklund & Hagbarth, 1966).

Studies of the Effect of Vibration on Human Subjects with Handicapping Conditions

The application of vibration over human skeletal muscle or tendon results is a predictable, noninvasive and convenient way to influence motor control via the tonic stretch reflex (Bishop, 1975b; de Gail et al., 1966; Hagbarth & Eklund, 1966b). Clinically, vibration is used as one form of proprioceptive stimuli to change the strength and distribution of spasticity by restoring the balance between facilitory and inhibitory neural mechanisms (Bishop, 1975b; Hagbarth & Eklund, 1969).

Persons with motor disorders have been studied. These primarily include adults and children with associated spasticity or rigidity resulting from brain damage. For the purposes of this review, these subjects are categorized as those with (a) spastic disorders, (b) rigidity and tremor, and (c) cerebellar syndromes and choreoathetosis. The studies on the effect of vibration are reviewed for each category of subjects, and are contrasted with the effect on nonhandicapped subjects.

Spastic Disorders

It was not possible to predict how a given person with central nervous sytem (CNS) or peripheral disturbances would respond to vibration even though the motor signs were identical to those of another person (Hagbarth, 1973). This was due to differences in CNS involvement (Bishop, 1975b; Burke et al., 1972). It is known that central lesions alter normal coordination between central pathways of alpha and gamma motor neurons (Hagbarth & Eklund, 1969). However, attempts to study the effects of vibration on persons with spasticity have yielded useful data for the clinician. These studies will be discussed in terms of the vibration-induced muscle contraction (the TVR), reciprocal inhibition on voluntary and involuntary movements, and the postvibratory potentiation effect.

Muscle Contraction

The TVR was reduced or absent in relaxed spastic muscle in the person with upper motor neuron lesions (Burke et al., 1972; Hagbarth & Eklund, 1966b; Lance et al., 1966). The effect of vibration could be increased when combined with voluntary effort (Hagbarth & Eklund, 1966b).

Burke et al. (1972) studied 34 adults having upper or lower motor neuron lesions resulting in spasticity. TVRs of the quadriceps and triceps surae muscles were measured. A TVR could be elicited in all subjects except those with complete spinal cord lesions. Isometrically, the TVR developed rapidly and reached a plateau with 2 to 4 seconds of the onset of vibration, and continued as long as vibration was maintained up to 5 minutes. As compared with normal muscle responses to vibration, these responses in spastic muscle started and stopped more abruptly. A phasic spike often preceded the tonic contraction. This twitch response at the onset of vibration was comfirmed in studies by Hagbarth and Eklund (1968) and Johnson et al. (1970). Clonus appeared only in those persons in which the phasic spike was present.

The ability to suppress the TVR voluntarily, as in nonhandicapped subjects, was present in all persons except those with spasticity resulting from a spinal lesion (Burke et al., 1972). These findings were substantiated by the observations of Hagbarth and Eklund (1966a, 1968).

It was generally accepted that the combined effect of vibration and maximal voluntary effort could result in muscle contractions 10 to 20 times that possible with vibration or voluntary effort alone (Hagbarth & Eklund, 1966b).

The length of the spastic muscle increased the strength of the TVR in some persons with spasticity. Burke et al. (1972) produced a dynamic muscular response during passive movement, but little or no response to static stretch. A TVR of the quadriceps muscle could not be elicited until the knee was flexed 30 to 45 degrees. Hagbarth and Eklund (1969) found that vibration of the spastic muscle caused increased resistance to stretch, whereas vibration to the antagonist weak muscle reduced spastic resistance to stretch.

Reciprocal Inhibition

It was thought that spastic muscles tended to impose additional inhibition on weak antagonists (Hagbarth & Eklund, 1969). In an earlier investigatin, Hagbarth and Eklund (1968) found that the TVR was usually weak in paretic muscle acting against spastic antagonists. However, when the paretic muscle was vibrated, the sustained contraction of the antigravity antagonist was always inhibited. When 20 adults received daily vibration to support voluntary attempts to contract paretic muscles, active range of motion was temporarily enhanced for 20 to 30 minutes. In some adults with severe chronic spasticity, however, the effect of vibration combined with voluntary effort was to elicit a motor pattern opposite that of the TVR. Enhancement of the autogenic inhibition and reciprocal excitation responses were therapeutically contraindicated.

In many adults with spasticity, the reflex contraction spread to functionally allied muscles and neighboring joints. For example, vibration of wrist flexors elicited the classic hemiplegic arm position of wrist flexion, elbow flexion-pronation and shoulder adduction (Hagbarth & Eklund, 1968).

Hagbarth and Eklund (1966b) investigated the responses of 16 adults with spasticity and diagnoses of hemiplegia, quadriplegia or paraplegia by vibrating both the paretic muscle and the antagonist muscle. They found that voluntary power was enhanced when the paretic muscle was vibrated. The improvement in voluntary power continued when vibration lasted for some minutes. Voluntary power of the paretic muscle decreased when the antagonist was vibrated. Bishop (1975b) noted that simutalneous vibration of several antagonists may relieve abnormal spastic postures, and that a reduction in the resistance of spastic antagonists can increase range of motion.

Potentiation

Vibration was shown to restore some voluntary motor control of a paralyzed muscle (Hagbarth & Eklund, 1966a, 1966b; Eklund & Hagbarth, 1968). There was disagreement in the literature describing its post vibration effects on voluntary movement. The findings have been described as no effect (Burke et al., 1972), moderate improvement for minutes after vibrating (Eklund & Steen, 1969; Hagbarth & Eklund, 1966b), and less severe weakness and spasticity 20 to 30 minutes after vibration (Eklund & Hagbarth, 1968). Other subjective claims have been attributed to the vibration effect. Burke et al. (1972) reported that some subjects felt more spasm-free and perceived that they could use their paretic muscle better for 1 to 2 hours after vibration. Eklund and Steen (1969) stated that voluntary control was enhanced as a result of improved body image during and after vibration in a study of 200 severely handicapped children with cerebral palsy.

Rigidity and Tremor

Burke et al. (1972) contrasted the effects of vibration on 15 adults with Parkinsons disease and 10 nonhandicapped subjects. There was no significant difference in the responses of the two groups. The TVR began seconds after the onset of vibration and increased slowly over 20 to 60 seconds. The rising phase was more rapid with higher frequencies. When vibration ceased, the contraction subsided in 0.5 to 2.0 seconds.

In a similar study that included 10 adults with Parkinsons disease, Hagbarth and Eklund (1968) found there was no improvement in voluntary motor performance with vibration. Although there was a normal variability between individuals in the strength of the TVR, no relationship was established between the degree of rigidity and the strength of the TVR. In some adults, the vibration increased tremor and impaired coordination. Reciprocal control was decreased as evidenced by a reduced ability to perform rapid alternating joint movements. Vibration of the calf muscles during standing with the eyes open caused backward falling reactions with no compensatory arm and body movements.

The TVR was potentiated by the Jendrassick maneuver in persons with spasticity and rigidity. The potentiation was most apparent in short muscle lengths (Burke et al., 1972).

Cerebellar Syndromes and Choreoathetosis

There was no therapeutic effect from vibration in some patients with cerebellar and extrapyramidal disorders (Hagbarth & Eklund, 1969). According to de Gail et al. (1966) and Hagbarth and Eklund (1968), the TVR was often absent or diminished in persons with cerebellar lesions. In some conditions, for example choreo-athetosis or intention tremor, vibration induced or increased the abnormal motor patterns. In some adults with hemiplegia, vibration upset muscle coordination in handwriting and accentuated the intention tremor. Falling reactions backward were elicited when vibration was applied to the calf muscles (Hagbarth, 1973), however, unlike persons with Parkinsons disease, adults with cerebellar lesions displayed a great variety of ineffective compensatory arm and body movements.

Children with Handicaps

Few studies have been published concerning the effect of vibration on children with severe handicaps. Eklund and Steen (1969) reported the effects of vibration during screening tests on 200 institutionalized children with severe handicaps secondary to cerebral palsy. Electrical vibrators with frequencies of 100 to 200 cycles per second and amplitudes of 1.5 mm were fastened over the muscle group near tendons of the group to be trained in "all conceivable situations" (p. 35). Vibration was applied from 30 seconds to 2 minutes. Two basic effects were noted in subjects with spasticity: (a) voluntary power of the vibrated muscle was enhanced as the spasticity of the antagonist was decreased, and (b) voluntary control was enhanced due to improved "body image" and the urge to move. There was no direct therapeutic effect when hypotonic muscles were vibrated. Vibration was beneficial to select children with athetosis or dystonia. Cautious application of the vibration and verbal direction were ncessary to avoid aversive reactions and torsion spasms. The study lacked information about design, method, measurement tools, reliability, and data analysis. Although some of the claims, for example, autogenic excitation, reciprocal inhibition, and improved body image were supported by previous studies of adults with handicaps (Burke et al., 1972; Hagbarth & Eklund, 1969; and others), this preliminary report was unproven and the results should not be accepted as empirically applicable in the clinic. The screening format lacked experimental control.

Vibration was applied to the masseter muscle, around the lips and under the chins of 10 institutionalized adolescents with mental retardation as part of a neurophysiologically based program to control tongue thrust (McCracken, 1978). Subject selection was determined by oral motor evaluation. Vibration was applied for 2 to 3 minutes to provide proprioceptive input to inhibit tongue thrust, not for muscle contraction. Vibration was also applied on the tongue to facilitate tongue lateralization. The results were improved ability to eat and a decrease in drooling. The study took place over two years. As in the critique of the previous study (Eklund & Steen, 1969), there was no report of the objective measures of reliability, data collection or data analysis.

Summary

The review of the litearture indicated that vibration was useful as a stimulus for muscle contracton (TVR) in the treatment of motor disorders. Generally, studies on the effect of vibration in nonhandicapped persons were shown to be widely variable across subjects, but highly reproducible in individual subjects. Parameters of the vibratory stimulus were generally accepted as a frequency of 100 to 200 cycles per second and an amplitude of 0.5 to 1.5 mm. The motor effects of vibration were (a) autogenic excitation (TVR), (b) reciprocal inhibition, and (c) suppression of phasic reflexes. Other variables that effect the strength of the TVR were muscle length, state of muscle contraction, timing and placement of the stimulus, and the central state of the subject.

Studies on the effect of vibration on adult subjects with handicaps, although lacking in numbers, have established that (a) the TVR, when combined with voluntary effort, was elicited in most subjects with upper motor neuron lesions, (b) the contracting antagonist muscles were inhibited by reciprocal innervation, and (c) the phasic reflexes were suppressed. Manipulation of these motor responses using vibration allows the clinician to enhance desired motor behaviors in some persons with handicaps. The few studies that attempted to measure the effect of vibration on children with motor and mental handicaps, were methodologically incomplete limiting clinical replication.

Potential Adverse Reactions

Bishop (1975) outlined limitations and contraindications in the use of therapeutic vibration. Duration was recommended not to exceed two minutes due to heat and/or friction generated. Therapeutic use of vibration with cerebellar disorders was contraindicated as in several instance it aggravated rather than alleviated the patient's motor handicap.

Vestibular System

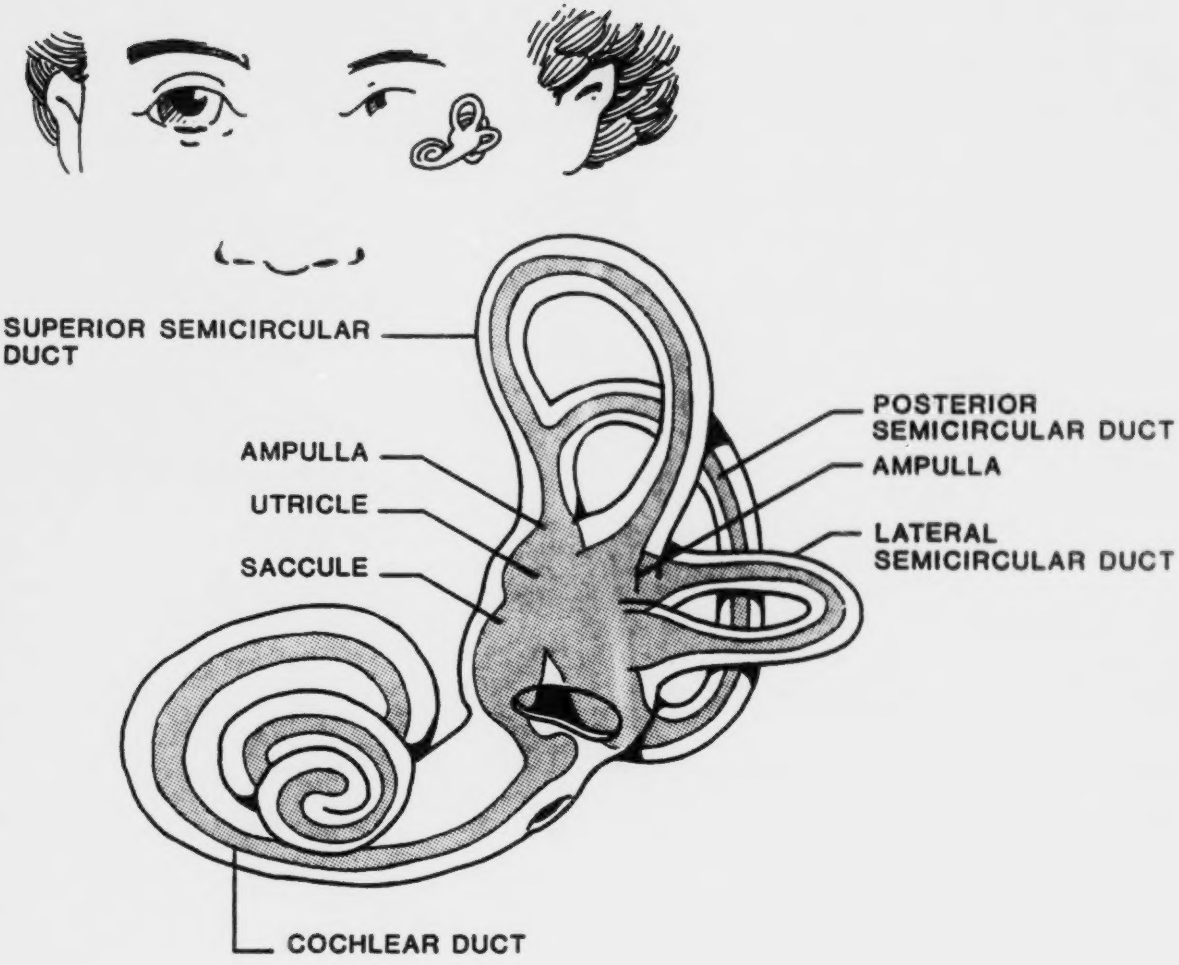
The vestibular system is the sensory/proprioceptive system of the body which functions to maintain the head and body in an upright position in relationship to gravity (Guyton, 1976; Weeks, 1979). It is the vestibular system along with other neuromotor reflexes, which signals the infant to lift the head from the prone position against gravity; it also allows the infant to maintain a stable visual image during movement of the head. As the child matures, the vestibular system continues to influence motor and visual behavior through the development of righting and equilibrium reactions. The influence of this system on the development of motor skill is significant. Erway (1975) noted "that any genetic or environmental factors which alters the normal development or maintenance of this elaborate inertial-guidance system may affect the development of early locomotor functions" (p. 24).

The vestibular system is capable of influencing muscle tone, eye movements, and general postural stability due to its linkage to the brain stem (the vestibular nuclei), the spinal cord, the extraocular eye muscles, the reticular formation and the cerebral cortex (Wilson, 1975). The vestibular system responds to movement, be it rotary acceleration, linear acceleration, or the natural gravitational pull. Therapeutic techniques to facilitate the vestibular system often consist of spinning in a chair (rotary acceleration), riding on a scooter board (linear acceleration), and sitting on a tilt board or inversion (responding to gravity). By manipulating a persons sensory input through therapy, Ayres (1975) hypothesized that the vestibular mechanism would be "activated" and the person will learn to adapt and respond to movement in a more effective way.

The following discussion will provide an overview of the anatomy and physiology of the vestibular system and an analysis of studies employing controlled vestibular stimulation as an independent variable with particular emphasis on rotary stimulation.

Structure and Function

The vestibular system is composed of the vestibular apparatus located in the inner ear and its connections to the central nervous system. The semicircular canals, the utricle, and saccule constitute the vestibular apparatus (Shuer, Clark & Azen, 1980). These three structures are physically connected and share endolymphatic fluid. The three semicircular canals (anterior/inferior canal, vertical/posterior canal, and horizontal/lateral canal) are set at right angles to each



SUPERIOR SEMICIRCULAR DUCT
AMPULLA
UTRICLE
SACCULE
POSTERIOR SEMICIRCULAR DUCT
AMPULLA
LATERAL SEMICIRCULAR DUCT
COCHLEAR DUCT

Figure 1. Anatomical position of semicircular canals and vestibular mechanism.

other with each canal representing a plane in space (Figure 1). The anterior canal reacts to rotation as in rolling, the vertical canal reacts to rotation as in a somersault, and the horizontal canal reacts to rotation around the central body axis (Heiniger & Randolph, 1981).

At the end of each canal is a bulbous portion called the ampulla which contains hair cells. The ampulla is covered by a gelatinous cupula. Angular and linear acceleration displace the endolympatic fluid, causing motion of the cupula which triggers nerve impulses from the hair cells to the vestibular nuclei to the brain (Mountcastle, 1968; Noback & Demarest, 1981). The movements of acceleration and deceleration produce the greatest distortion of the hair cells initiating the sensory impulse (Heiniger & Randolph, 1981). The ampulla terminates into the utricle, which through the endolymphatic duct, connects with the smaller sac, the saccule. The hair cells of the utricle and saccule are also covered by a gelatinous wedge.

Five sensory receptors are located within each vestibular apparatus (Barr, 1974; Guyton, 1976; Grollman, 1978). Three of the receptors are situated within the semicircular canals--one in each ampulla. These receptors are called cristae. The other two receptors, the macullae, are located within the utricle and saccule. Although they differ in structure, both types of sensory receptors, the cristae and the macullae, contain highly specialized hair cells (Grollman, 1978). When these hair cells are stimulated, they send nerve impulses through the vestibular nerve to the brain. Stimulation occurs by movement of the fluid, or endolymph, within the structures; movement of the endolymph is caused by movement of the head in space. Therefore, when the head is turned or tilted to one side, gravity and inertia causes the endolymph to bend and stimulate the hair cells which then, in turn, send impulses to the brain.

When sending impulses to the brain, the two sensory areas possess different functions. The cristae repond mainly to angular acceleration, or rotation, and to changes in the direction of movement. Therefore, the semicircular canals are often called the kinetic labyrinth. The acceleration required to stimulate the canals averages about one degree per second. That is, the velocity of angular motion must be as much as one degree per second by the end of the first second, two degrees per second within two seconds, three degrees per second by the end of the third second, and so on, for an individual to barely detect an increasing velocity (Guyton, 1976). In contrast, the macullae respond mainly to the pull of gravity and linear acceleration. Because of this, the utricle and saccule are considered to be the static labrinth (Grollman, 1978; Guyton, 1976). Both of these areas, through their highly specialized functions, inform the brain of the exact position of the head in space and determine any movement that occurs; the body is then able to make the appropriate adjustments to this movement.

The messages sent to the brain influence spinal motor centers for movement of the head, trunk, and limbs; occulomotor centers for movement of the eyes; and the flocculonodular lobe of the cerebellum for balance (Pompeiano, 1974). The vestibular system also stimulates autonomic centers of the medulla, mid-brain, thalamus, and cerebral cortex which affect vascular changes, perspirations, salivation, gastrointestinal effects, yawning and sleepiness (Shuer et al., 1980).

A basic function of the vestibular system is to stabilize body and eye positions to ensure precise, goal-directed movements and clear vision (Shuer et al., 1980; Weeks, 1979). The vestibular system also enables the organism to detect whether any given sensory input (i.e., visual, tactile, or proprioceptive) is associated with movement of the body or is a function of the external environment (Ayres, 1974). De Quiros (1976) noted that

> proprioception and the vestibule have a closely linked anatomo-functional relationship, and intervene basically in furnishing adequate information with respect to the body itself (muscular tonus, posture, etc.) and with the stimuli of the immediate environment (p. 51).

Quantitative Review of Studies

Ottenbacher and Petersen (1984) employed a quantitative review method (meta-analysis) to examine the results of studies that explored the effectiveness of vestibular stimulation as a form of sensory stimulation. The methodology for reviewing research studies is based on the same standards of empirical inquiry and experimental control as traditional primary research. In an article summarizing this approach to synthesizing research results in clinical pediatrics (Ottenbacher & Peterson, 1983) the authors provided the following explanation for the chosen methodology.

> The procedures referred to as quantitative reviewing or meta-analysis, are designed to treat the review process as a unique type of research endeavor that produces a quantitative synthesis of research results (Cooper, 1982; Glass, 1976). The goal of a quantitative review is to summarize previous research by statistically integrating conclusions from studies believe to address a similar or identical hypothesis (Cooper, 1979). The procedures provide a systematic mechanism for investigating variation in study characteristics such as sampling, design procedures, and type and number of dependent and independent variables (Glass, McGraw & Smith, 1981). Variance in these variables is then related to study outcome (p. 424).

The stages employed in a quantitative review include: (1) problem formation; (2) data collection; (3) data evaluation; (4) analysis and interpretation; and (5) reporting results. Quantitative reviewing procedures constitute a significant advance over the traditional narrative methods of integrating empirical research in an area of interest.

Ottenbacher and Peterson (1984) located 67 non-overlapping research report titles from an on-line computer search of Psychological Abstracts, Index Medicus, Dissertation Abstracts International and Current Index to Journals in Education--Resources in Education (ERIC). An examination of the bibliographies of retrieved studies resulted in the location of additional information. The following specific criteria were used to judge the relevance of the abstracts and full report: (1) the study investigated the effects of controlled vestibular stimulation as at least one of the independent variables; (2) dependent variable(s) were defined by improvement on any measure that evaluated cognitive/language ability, motor/reflex functions, visual/auditory alertness or physiological (weight gain, growth) functions; (3) the investigation included a pediatric population; (4) the study's design and method of analysis reported a comparison between at least two groups, i.e., one receiving vestibular stimulation and one that did not. The study reported findings and results in a manner that allowed quantiative analysis. It should be noted that within subjects experimental designs were included where the comaprison or control group was the same as the experimental group.

Of the 67 studies located, 14 studies met the criteria outlined previously. The mean d-index for the 31 hypothesis tests was 0.71 (50,±.62). The U3 values associated with the d-index of .71 is 76.1 which indicates that the average performance of subjects in experimental groups or conditions receiving some form of vestibular stimulation was better than 76.1 percent of the subjects in comparison or control groups not receiving the stimulation. Subanalysis across hypothesis tests according to type of stimulation received, the type of dependent measure employed, and the diagnostic category of the subjects were performed. The analysis for the different variations of the independent variable indicated that the mean effect for rotary stimulation was approximately twice that of linear/vertical vestibular stimulation. Similarly the mean d-index for outcome measures of motor/reflex function and visual/auditory ability were more than double the mean d-indexes for hypothesis tests using dependent measures categorized as cognitive/language or physiological. The effect sizes anlayzed according to diagnostic category revealed that vestibular stimulation had the greatest effect on children diagnosed as handicapped (e.g., cerebral palsy and/or mental retardation).

A total of 533 subjects participated in the 14 studies included in the review. One hundred and five subjects were infants and children with overt developmental delay (e.g., cerebral palsy and/or mental retardation). Four of the 14 studies investigated the effects of rotary vestibular stimulation on reflex/motor behavior in the above populations (Chee, Kreutzberg & Clark, 1978; Ottenbacher, Short & Watson, 1981; Rogos, 1977; Sellick & Over, 1980). Three of these studies were known to the investigators; the fourth study (Rogos, 1977) was a dissertation. These three studies that met the criteria outlined by Ottenbacher and Peterson (1984) are reviewed in the following discussion.

All three studies employed group designs with experimental and control groups. Similarities in the application of the independent variable included a rapid 1 to 2 second acceleration, a 60 second period of constant velocity at 100 deg/sec (16.7 rev/min) and an impulsive stop. The preceding defined one spin which was applied in a clockwise (CW) and then counterclockwise (CCW) direction. The methodologies across these studies differed in the total duration of vestibular stimulation (i.e., number of spins) per session, positioning of subjects for intervention (to maximize semicircular canal stimulation), duration of the intertreatment interval and the spacing of sessions.

Two of the studies (Chee et al., 1978; Ottenbacher et al., 1981) reported statistically significant gains in reflex/motor development while one study (Sellick & Over, 1980) demonstrated no appreciable differences between the experimental and control group. Interestingly two of the studies with conflicting results were almost identical in terms of the length of the study, frequency of intervention sessions, and positions utilized for the intervention (supported sitting, right and left sidelying). Chee and his colleagues applied six spins with a total of six minutes of stimulation while in the Sellick and Over study ten spins (two additional spins in the right and left sidelying position) with a corresponding duration of ten minutes of stimulation were applied. Although the total duration of stimulation was not compatible perhaps the more significant difference involved the intertreatment interval. Chee et al. utilized a 30 second intertreatment interval between spins whereas Sellick and Over did not specify either the occurrence or duration of this interval in their methodology. According to a later study by McLean and Baumeister (1982) a 30-60 second rest period is necessary to avoid the cupula returning from a position of maximum deflection. In the Ottenbacher et al. (1981) study a 60 second intertreatment interval separated each of the eight spins with the child positioned in supported sitting and supine. Results from the study revealed that subjects receiving a combined program of sensorimotor therapy and controlled vestibular stimulation made significantly greater gains on measures of reflex integration and gross motor development than the control subjects receiving a program of sensorimotor therapy alone. The need for additional research on both the parameters and efficacy of vestibular stimulation was a recommendation made by all of these investigators.

Potential Adverse Reactions

Johnson and Jonijkees (1974) and Shuer, Clark and Azen (1980) have indicated that vestibular stimulation may affect vascular changes, perspiration, salivation, the gastro-intestinal system,and respiration, due to connections with the autonomic centers of the medulla, midbrain, thalamus, and cerebral cortex. Although such side effects of vestibular stimulation may be possible, literature in this area is conflicting.

Chee et al. (1978) screened their subjects for cardiac problems or recurrent seizures, and selected only those who had no history of either condition. Ayres (1975) suggested monitoring autonomic responses such as flushing, blanching of the face, unusual perspiration and nausea, as well as seizures. Ayres (1975) noted that evidence of a detrimental effect of vestibular stimulation on seizure activity was inconclusive. She made no mention of either screening or monitoring subjects with a history of cardiac problems. Ayres further suggested the importance of proper positioning of subjects during vestibular stimulation. She recommended the flexed position to avoid increasing muscle tone, especially for those subjects who are already exhibiting high muscle tonus.

Many studies have presented vestibular stimulation either in a dimly lit or darkened room (Chee et al., 1978; Clark et al., 1977; MacLean & Baumeister, 1982). This step was taken as a precaution against seizures, regardless of the lack of evidence to support the notion that vestibular stimulation may induce seizures. Little effort was made to assess the effects of vestibular stimulation on seizure activity in any of these studies. Kantner, Clark, Atkinson, and Paulson (1982) investigated more closely the effects of vestibular stimulation on seizures. After taking baseline data on electroencephalographic (EEG) disturbances of ten seizure-prone children, the investigators exposed the subjects to caloric stimulation by placing warm and cold water into the ear canals. An electronystagmographic (ENG) record confirmed the effectiveness of stimulation. Posttest EEG's depicted no accentuation of abnormal brain wave patterns as a result of this type of vestibular stimulation. In fact, a significant reduction in abnormal high voltage activity (paraxysmal activity) was noted for 6 of the 10 subjects.

Inversion

Inversion is a therapeutic position used by occupational and physical therapists to stimulate and strenghren extensor muscles of children with various handicapping conditions. It is hypothesized that inversion activates several neurophysiological reflexes and stimulates the vestibular system to produce neck and trunk extension. To assume this position, the person's head is placed lower than the trunk of his or her body. Although there is very limited research regarding the therapeutic use of inversion, it is clinically used widely in programs for children with a variety of motorically handicapping conditions.

Neurophysiological Response

There are two neurophysiological responses associated with the inverted position, the muscle stretch response and the baroreceptor response. These neurophysiological responses are explained by a description of the muscle spindle and its function, the practical applications of the inverted position in relation to the muscle spindle, and the function and effects of the carotid sinus receptors when the body is in the inverted position. The neurophysiological response of muscle stretch has been described as follows:

> The simplest and best understood of all peripheral mechanisms, the stretch reflex...is the most powerful and most universally applicable of all facilitory mechanisms. The large-diameter ...afferent fibers from the stretch receptors within the muscle spindles make powerful monosynaptic excitatory connections with the alpha motoneurons innervating the muscle...They also make polysynaptic inhibitory connections with motorneurons innervating the antagonistic muscles, providing the physiological basis for Sherrington's reciprocal innvervation principle. Thus, the therapist may use muscle stretch for facilitation of the muscle stretched, or relaxation of its antagonist (Basmajian, 1980, pp. 48-49).

Muscle spindle. Early theories explaining the neurophysiological concepts were introduced by Sherrington in 1884. He described muscle spindles as highly organized sense organs (Heiniger & Randolph, 1981). These spindles lie "in parallel" with the muscle fibers and are stretched as the muscle is stretched (Mountcastle, 1968, p. 1707). Basmajian (1974) noted that both tonic and phasic motor units exist in mammals as well as invertebrates. He reported on research which showed "peculiar motor potentials" coming from "special tonic motor units" which respond only to stretch (p. 92). Stockmeyer and Rood used the muscle spindle concept as a basis for their treatment approaches.

Conflicting information exists in the literature regarding the function and neurophysiological make up of the muscle spindle. The muscle spindle is a sensory receptor consisting of nuclear bag and nuclear chain fibers with contractile fibers at either end (Figure 2). These fibers lie in parallel with those of the extra fusal fibers of the muscle. The muscle spindle has two sensory neurons, the Ia fibers and the II fibers. According to Crutchfield and Barnes (1973), the Ia phasic sensory recpetor responds to quick stretch anywhere in the range and is facilitory to its own muscle and inhibitory to its antagonist muscle. The Ia tonic receptor responds to maintained stretch in the submaximal range and is facilitory to its own muscle and inhibitory to its antagonist. The II, or secondary ending, responds to maintained stretch in the maximal or lengthened range. If a maintained stretch is applied to the extensor in its maximal range, the flexor will be facilitated. The extensor drives the flexor in balanced co-contraction. According to Matthews (1969), the relationship between the Ia receptors and II receptors is not so clearly defined. Matthews suggested that both the group II and the group Ia fibers are responsible for the maintained stretch reflex. Eccles and Lundborg (1980), reported that stimulation of group II fibers occasionally results in facilitation of extensors and inhibition of flexors. This is a direct contrast to the view presented previously by Crutchfield and Barnes (1973). Munson, Sypert, Zengel, Lofton, and Fleshman (1982) indicated that several roles for the group II fibers have been suggested; but none have been definitely established. In summary, it appears that the muscle spindle plays a role in the muscle stretch response, but the exact mechanism is not clearly understood at this time.

The practical application of the neurophysiological concept in relation to the inverted position involves using natural physiological

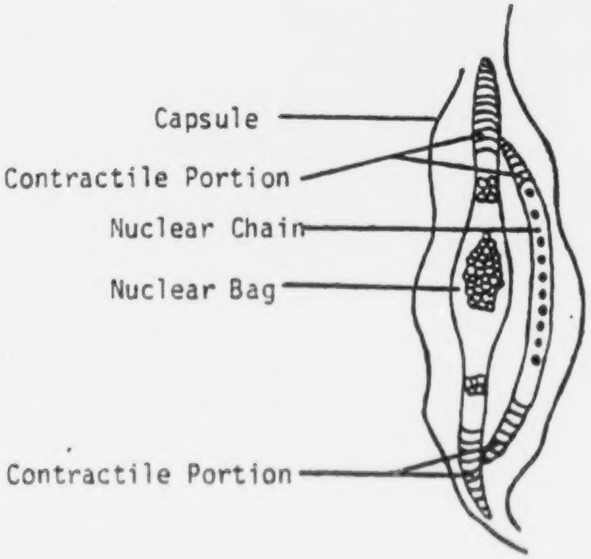


Figure 2. Muscle spindle

reactions and techniques developed by Rood. Heiniger and Randolph (1981) stated that the inverted position causes a generalized decrease in muscle tone and thus a decrease in fusimotor activity; the hypersensitive muscle spindles in spastic muscles can thus be inhibited. The tonic labyrinthine input from the vestibular system to the motor neurons of the neck and midline trunk extensor muscles causes the extensor muscles to contract. In the inverted position, the extensor muscles are placed in their maximal range facilitate the flexors to bring about co-contraction (Heininger & Randolph, 1981).

Baroreceptor reflex. The baroreceptor reflex is a neurophysiological response elicited when a person is placed in an inverted position. The baroreceptor reflex is a circulatory reflex which is initiated by pressure receptors called baroreceptors or pressoreceptors. These receptors are located in the walls of large, systemic arteries, such as the carotid sinus and aortic arch (Figure 3). They are stimulated when they are stretched. Baroreceptors respond rapidly to changes in arterial pressure, and they respond more to rising pressure than to stationary or falling pressures. The effect of stretching the baroreceptors, as in inverting a person and causing the carotid sinus to fill, results in vasodilation throughout the circulatory system along with decreased cardiac rate and decreased strength of contraction. The end result is a decrease in blood pressure (Guyton, 1971). This decrease in blood pressure in the inverted position results in a trophotropic response which is a generalized decrease in muscle tone (Gellhorn, 1967). This relaxation is important for reducing tone in spastic muscles.

A discussion of the ergotropic and trophotropic states is important to this explanation of baroreceptors and the inverted position. Gellhorn's

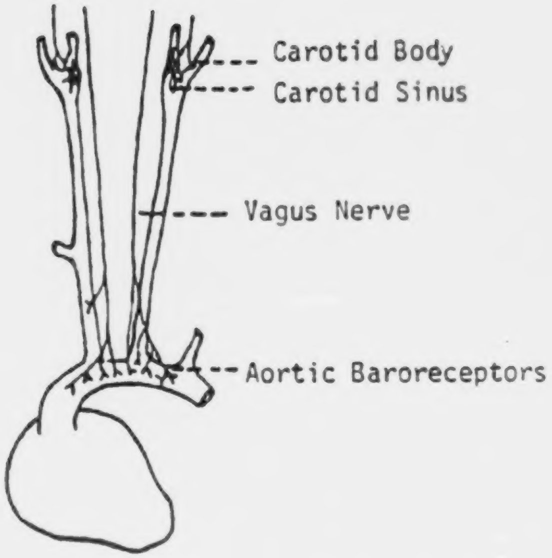


Figure 3. Baroreceptor mechanism

(1967) research showed that in the ergotropic state, sympathetic discharges caused an increase in the activity of muscles. In the trophotropic state, the parasympathetic discharges were associated with a decrease in activity and responsiveness of the somatic nervous system. Gellhorn found that trophotropic or parasympathetic "tuning" was increased by means of baroreceptor activity in the carotid sinus. An increase in pressure in the carotid simus resulted in a decrease in muscle activity.

Vestibular mechanism. In addition to neurophysiological responses, a vestibular response is facilitated through inversion. The vestibular concept is described by Heiniger and Randolph (1981).

> Vestibular sensory input is related either to motion or position of the head in relation to the force of gravity. The integration of the motion portion of the vestibular mechanism may be demonstrated by dizziness or nystagmus or both after stimulation. The position portion of the vestibular mechanism may be used in treatment by placing the individual in the inverted position. This position produces three sequential responses:
>
> 1. Decreased blood pressure from the carotid sinus stimulation.
> 2. Decreased generalized muscle tone from fusimotor inhibition.
> 3. Increased fusimotor activity to key extensor muscles from the vestibular system. (p. 85)

The vestibular system detects the position and the motion of the body in space by integrating information from the peripheral receptors located in the inner ear on either side of the head (Kendal & Schwartz, 1981). This concept has been developed through the years by various researchers. Magnus (1920) studied the physiology of posture postulating that it was an "active process" and "the result of the cooperation of a great number of reflexes" (p. 1). He stated that the labyrinthine righting reflexes provided for orientation of the head in relation to space with gravity as the controlling influence. He also concluded that the head was righted by labyrinthine, tactile, and optical stimuli; while the body was righted by proprioceptive and tactile stimuli. This righting apparatus was located in the brain stem and was involuntary in nature.

Tokizane, Murao, Ogata, and Kando (1951) followed with their study demonstrating that maximal extensor tone was achieved at 0° or the head-down position in non-handicapped adult males. Their research showed that attitudinal reflexes such as tonic neck, lumbar, and labyrinthine reflexes exerted an influence on muscle tone.

The vestibular apparatus is made up of five components--three semicircular canals, saccule, and utricle. The canals register movement of the head in any plane by means of sensory hair cells that move in the cupula in the enlarged end of the canal called the ampulla. There are also receptor cells in the saccule and utricle which detect information about the body position with regard to gravity. Gillette (1974) indicated that the utricle is the main receptor mechanism. When the utricle is stimulated by changing the position of the head in respect to gravity, tone is shifted from one postural muscle group to another. Kande (1981) emphasized that the bidirectional nature of hair response, along with the bilateral interaction of the labyrinths, is an advantage in providing multiple indications of head movement and position. Fluid or otoconia in the saccule and utricle bend the hair cells when the head position is suddenly changed. Hair cells in the saccule respond to linear side-to-side motion and those in the utricle respond to linear up-and-down motion. When the hair cells are bent, nerve impulses are sent to the vestibular (Scarpa's) ganglion. Impulses from the canals, saccule, and utricle move from the vestibular ganglion into the ascending and descending pathways to the vestibular nuclei in the brain stem; those impulses from the saccule and utricle end in the lateral vestibular nucleus (Dieter's) and the medial vestibular nucleus. The lateral vestibular nucleus sends impulses down the lateral vestibular tract to the portion of the spinal cord serving the cervical and thoracic levels. A tonic excitatory effect on postural tone is exerted on spinal extensors; this effect is strongest to motoneurons supplying neck muscles, emphasizing the important relationship between the membranous labyrinthine vestibular nuclei and the neck muscles (Heriza, 1978). Along with excitation by the lateral vestibular tract, there is an inhibition brought on by the medial vestibular tract; but a balance is maintained to allow for extensor contraction (Heiniger & Randolph, 1981).

The anterior canals are the components of the vestibular system that are stimulated during inversion. Impulses from these canals travel to the vestibular nuclei in the brain stem which send messages to the cervical and thoracic muscles to bring about extension of the neck and trunk (Mountcastle, 1980).

Combining Gellhorn's (1967) ergotropic and trophotrophic theory and Tokizane's (1951) labyrinthine theory, clinicians have developed applications of the inverted position as therapeutic treatment procedures. They used the inverted position to obtain maximum extensor tone and to achieve a parasympathetic or relaxed state to combat spasticity. Buttram and Brown (1977) recommended that inversion be used with children who have abnormal muscle tone, either too much or too little. They sggested that inversion normalizes muscle tone (e.g., to decrease hypertonicity of flexors and hypotonicity of extensors) and strengthens the muscles that provide stability at the neck, trunk, hips, elbows, wrists, and ankles. As the child is encouraged to extend his arms and hands, "parachute reactions are stimulated" (Buttram & Brown, 1977, p. 26). Rood also advocated an inverted position to facilitate neck and trunk extension, along with elbow and wrist extension to develop the protective parachute arm position (Heiniger & Randolph, 1981).

An overview of the literature on the effects of the inverted position indicates that the neurophysiological responses (muscle stretch and baroreceptor) combined with the functions of the vestibular mechanism produce three major effects: reduced blood pressure, generalized relaxation or reduced muscle tone, and increased stimulation to key extensor muscles. Thus, it can be theorized that the inversion procedure can be therapeutically used to strengthen neck and trunk extensors.

Potential Adverse Reactions

Clinical caution should be exercised in the use of inversion with children who have shunts (for hydrocephalus), heart conditions, epilepsy and unarrested hydrocephalus (Buttram & Brown, 1977). For children with improperly functioning baroreceptors or who have had Cerebral Vascular Accidents (CVA's) it is recommended that blood pressure be taken periodically before, during, and after the inversion procedure. All children should be monitored for nose bleeds, facial flushing, ringing of the ears, difficult breathing, perspiration, nausea, and an increased pulse rate.

Progress to Date

Quantitative Assessment System

The limitations of traditional developmental scales with a handicapped population have been enumerated by both clinicians and researchers

(Cohen, Gross, & Haring, 1975; Edwards & Edwards, 1970; Folio, 1976; Guess, Warren, & Rues, 1978; Mira, 1977; Roberts, Bondy, Mira & Cairns, 1978; Whitney, 1978). The major deficiencies identified include: (1) the absence of operationally defined and quantifiable behaviors; (2) the utilization of a simplistic occurrence/nonoccurrence scoring strategy; (3) the absence of assessment items sensitive to incremental changes in behaivor; and (4) the assumption that handicapped children's development parallels that of the nonhandicapped but at a slower rate. The cumulative effect of these limitations has resulted in an assessment strategy that does not address precise quantification of present skill level, rate of acquisition, or covariations in emerging behaviors.

These limitations confound our efforts to monitor early intervention programs. According to Roberts et al. (1978) "Infant scales, no matter how frequently administered, cannot provide information about how an emerging behavior is changing nor allow the study of differential rates of development and interactions or different behaviors" (p. 256). The assessments presently available are inadequate for documenting the effectiveness of a procedure or in comparing therapeutic treatment procedures to develop requisite, functional sensory/motor skills with this population.

In response to the limitations confronted when attempting to use most assessment devices with severely handicapped infants and young children, we and our colleagues initiated a program of research several years ago to develop an alternative assessment strategy designed to minimize these deficiencies. Our goal was to design an assessment system that could be used to both identify developmental deficiencies and to provide information on very small incremental skill increases by the child. The resulting system can also be used to measure the direct effects of therapeutic interventions on these behaviors.

The following discussion will briefly describe the characteristics of this system and the development process. A very detailed presentation of the procedures, the basis for their development, and the results of reliability analyses on their use is available upon request from the Early Childhood Institute at the University of Kansas (cf. Guess, Warren & Lyon, 1980; Guess, Rues, Warren, Lyon, & Janssen, 1981).

The initial task in developing the system was the identification and selection of "critical" sensory/motor behaviors that are normally acquired during the first 18 months of life, with special attention given to identifying those skills that emerge during the first year. Critical skills were identified as those sensory/motor behaviors that were commonly observed in the majority of developmental sequences and that have obvious functional importance to the child's overall adaptive behavior. A major source for the identification and selection of the skills was the publication of Cohen et al. (1976). These authors developed a well-documented profile of functional sensory/motor skills by expected age of occurrence. The skills identified represent important "developmental pinpoints" (Cohen et al., 1976).

The list of sensory/motor "developmental" pinpoints selected for measurements are listed as follows under their major sensory/motor categories.

Visual Orientation: fixation, tracking and scanning (vertical and horizontal)

Fine Motor: reach, grasp, release, and transfer (objects)

Gross Motor: Stability: head erect and sitting

Gross Motor: Mobility: rolling, crawling, creeping and walking

Specific, quantitative measurements of these sensory/motor skills were developed to facilitate fine focus analyses of their development. A three-step process was followed in developing these measures. First, an in-depth literature review of studies, investigations, and existing instruments and developmental milestone (e.g., visual fixation, reach, grasp, head erect) was conducted. Second, we developed descriptions of subcomponent skills related to each major developmental milestone that could be measured in quanitative terms, and an approximation of the various age levels (in months) in which these subcomponent skills were normally expected to occur. Third, we developed the actual quantitative procedures to measure the acquisition and emergence of these skills.

The extensive literature reviews that we initially conducted had two purposes. First, they allowed us to identify any techniques or procedures that had already been designed to measure, quantitatively, the particular sensory/motor skill under investigation. Secondly, the reviews were important in establishing preliminary hierarchies of discrete skills that should be measured in the possible developmental sequence of each area. This normative data provided guidelines for identifying subcomponent skill hierarchies.

The bulk of our efforts were directed towards developing specific quantitative measurement procedures for each of the subcomponent units in the skill hierarchies. These procedures have been described in sufficient detail so that other persons can use them in educational and clinical treatment settings, assuming they have adequate backgrounds in basic observational measurement methodologies. They do not require sophisticated or expensive equipment or apparatus. The specifications of each measurement procedure included functional information in each of the following areas:

Description of behavior(s). This included a clear and observable definition of the behavior to be measured.

Conditions for observation. Explicit descriptions were presented of the conditions under which the measures were taken. These included such considerations as: the position of the child at the start of the observation period; a detailed explanation, if necessary, of how the child was to be moved or handled during the observation period; and, any variations in the conditions that were desired when observing a child across different settings.

Observation settings. This required explanations of the various settings in which the observations were made. These ranged from structured settings where the child was manipulated for purposes of taking data to nonstructured (free operant) settings where the behavior was allowed to occur spontaneously. In each case, specific details were provided on how the particular environment was to be arranged, including the location of materials, equipment, observers, etc.

Materials and equipment. Descriptions were provided of any specific materials or special apparatus used in the measurement procedures. These descriptions included dimensions as well as methods of construction. Where appropriate, diagrams of the apparatus or special equipment were provided.

Data recording procedures. This included identification of the particular procedure(s) used to meausre the specified behavior, including the time limits of the observation period, the recording system used (e.g., frequency, duration, interval) and copies of the data sheets. In some instances the procedures required multiple observations of behavior (e.g., recording arm positions simultaneous with measures of head erect).

Interobserver reliability. The conditions for taking interobserver (and intraobserver) measures of reliability were carefully specified. The types of reliability measures to be taken were also specified as well as the frequency of the measures.

Following the development of the measurement procedures, they were field-tested for 3 to 4 years. During this period of time, the procedures were replicated across handicapped and nonhandicapped populations, revised, and utilized in longitudinal studies. At each step in the process, the reliability of the procedures within and across subjects and over time were extensively investigated and reported (c.f. Guess et al., 1981). In summary the development of this assessment system provided a basis for the research results to be reported. Without a precise, reliable assessment system capable of tracking small increments of motor skill development by children with severe handicaps a fine-grain experimental analysis of the effects of the various therapeutic strategies would be impossible.

OBJECTIVES

Objective 1. To experimentally determine the effectiveness of specific therapeutic intervention techniques on the development of basic motor skills in severely handicapped infants at different points on the developmental continuum.

Although different therapeutic techniques have been proposed and utilized by physical and occupational therapists, very little scientific evidence exists attesting to their effectivness. These techniques include vibration, vestibular stimulation, and inversion. Objective 1 was designed to experimentally determine the effectiveness of these techniques. Among the questions addressed were: (1) What behaviors are most effected by each of these procedures? (2) What is the optimal duration of each application? (3) Are these techniques differentially effective across varied handicapping conditions and ages? (4) How long after treatment do the effects maintain and to what extent do they generalize? (5) What are the effects of long term application on generalization and maintenance of therapeutic changes? (6) What guidelines should be followed to insure the safe us of these techniques?

These questions were addressed in the course of implementing Objective 1 of the research plan. The effects of each technique were investigated, using individual subject designs, with key gross motor behaviors along the continuum of basic motor development. These behaviors included head erect, upper extremity weight bearing, sitting, and ancillary behaviors. The effectiveness of the techniques was studied with a representative population of severely handicapped infants and young children with deficits in one or more of these behaviors.

Objective 1 was the basis for completing the other two objectives. Thirteen individual studies were conducted across the three techniques. These studies were conducted and completed throughout the three years of the grant period.

Objective 2. To explore the relationship between the development of specific motor skills and other associated motor skills.

Motor development normally proceeds along a continuum in which more sophisticated skills are constantly being developed from simpler, already acquired skills. It is likely that certain basic skills, such as head erect, are prerequisite for the development of numerous other skills (e.g., visual, upper extremity weight bearing, sitting, etc.). Likewise, failure to develop these skills may inhibit or block the development of a wide array of other skills. In Objective 2 a basic hypothetical question was addressed: What is the effect of treating certain key motor behaviors on the development of other associated skills on the continuum of motor development? More specifically, what covariations exist between the development of specific motor skills and other associated skills? For example, if we improve the ability of a child to sit, what effect will this have (if any) on protective extension and postural fixation while sitting?

Objective 2 was carried out utilizing probes correlated with the basic experimental designs that were followed as Objective 1 was conducted. Each time a child reached a criterion point in treatment, the probes were conducted using the measurement system previously developed and described in the method section of this report.

Objective 3. To experimentally determine the effectiveness of therapeutic intervention packages on the development of basic motor skills in severely handicapped infants at different points on the developmental continuum.

In Objective 1 a range of basic questions were addressed concerning the effects of the specific therapeutic techniques being investigated. It was assumed that once these effects were known, the optimal therapeutic utilization of them would be in various combinations applied within an individualized curriculum sequence. The effectiveness of this curriculum model in general applications with severely handicapped individuals has been established (Guess, Horner, Utley, Holvoet, Maxon, Tucker & Warren, 1978). Based on the results of the preceding studies, vestibular stimulation was selected as the independent variable for this final study. The targeted behaviors for this study were selected from each subject's individual education plan. These behaviors were arranged developmentally and functionally in an individualized curriculum sequence with a detailed task analysis for each behavior.

METHOD

The research plan was designed to meet the three objectives over a period of 36 months. Objective 1 and Objective 2 were carried out during the 3 years of the project. Objective 3 was carried out during the final 6 months of the funding period.

The following methods section includes a description of the child population and settings that were utilized throughout the experimental program, the research designs employed, the measurement system used in completing all three objectives, and the specifics of the therapeutic intervention techniques that were studied.

Subjects

Subjects for these studies included infants and young children with severe handicaps between birth-6 years of age. Specific criteria for subject selection are detailed for each dependent variable (see Measurement System). Criteria included specification of the behavioral level of the target response expressed either as frequency or duration of the behavior to be investigated. Contraindications for application of the various techniques to certain diagnostic groups are also included and were drawn from the available literature.

Characteristics of the children studied included multiple handicapping conditions of pre-, peri-, and post-natal onset. These were youngsters who presented with cerebral palsy, seizure disorders, mental retardation, auditory and/or visual impairments. Characteristics of subjects involved respectively in studies employing vibration, vestibular stimulation, and inversion are presented in narrative and tabular form for each study.

Settings

The research studies were conducted in the following sites:

1. Site: Kansas University Medical Center
39th and Rainbow
Kansas City, KS

Program: Severely/Multiply Handicapped Preschool

Responsible Agency: University of Kansas Department of Special Education

Number of Children: 8

Ages: 2-6 years

School Hours: Monday - Thursday, 9:30 - 3:00

Description of Population: preschool children with severe mental retardation and at least one additional handicap. Additional handicapping conditions include cerebral palsy, visual and/or auditory impairment and emotional disturbance.

Length of Project Participation: 1982 - 1986 (3 years)

2. Site: Kansas University Medical Center
39th and Rainbow
Kansas City, KS

Program: Diagnostic and treatment programs offered in the interdisciplinary setting

Responsible Agency: Children's Rehabilitation Unit/University Affiliated Facility

Number of Children: 10-15

Ages: 0-5 years

School Hours: Monday - Friday, 8:30 - 4:30

Description of Population: Mildly to severely retarded children with such medical diagnoses as cerebral palsy, Down's syndrome, psychomotor and growth retardation, and seizure disorder. These children are generally seen for out-patient services through the Occupational and Physical Therapy Divisions.

Length of Project Participation: 1983 - 1984 (1 year)

3. Site: United Cerebral Palsy Association of Greater Kansas City
106 E. 31st Terrace
Kansas City, MO

Program: United Cerebral Palsy Infant Development Center

Responsible Agency: United Cerebral Palsy Association of Greater Kansas City

Number of Children: 12

Ages: 0-4 years

School Hours: Monday - Friday, 9:00 - 3:00

Description of Population: infant and preschool children with cerebral palsy and at least one othr handicapping condition. Additional handicapping conditions include mental retardation, auditory and visual impairments.

Length of Project Participation: 1982 - 1986 (3 years)

4. Site: Kansas City Regional Diagnostic Center
22nd and Holmes
Kansas City, MO

Program: Multiply Handicapped Preschool

Responsible Agency: University of Missouri at Kansas City
University Affiliated Facility

Number of Children: 18

Ages: 1-6 years

School Hours: Monday - Friday, 8:00 - 3:00

Description of Population: preschool children who are moderately to severely retarded, with such medical diagnoses as cerebral palsy, Down's syndrome, Acardi syndrome, seizure disorder, and psychomotor and growth retardation.

Length of Project Participation: 1982 - 1984 (2 years)

5. Site: Katherine Carpenter Elementary School
9700 W. 96th Street
Overland Park, KS

Program: Multiply Handicapped Classroom

Responsible Agency: Shawnee Mission School District

Number of Children: 8

Ages: 5-10 years

School Hours: Monday - Friday, 8:15 - 3:00

Description of Population: primary school-aged children with severe mental retardation and at least one additional handicap. Additional handicapping conditions include cerebral palsy, visual and/or auditory impairment and emotional disturbance.

Length of Project Participation: 1984 - 1985 (1 year)

6. Site: Tomahawk Elementary School
6301 W. 78th Street
Overland Park, KS

Program: Non-Categorical Kindergarten

Responsible Agency: Shawnee Mission School District

Number of Children: 8

Ages: 5 and 6 years

School Hours: Monday - Friday, 8:30 - 2:30

Description of Population: kindergarten-age children with mild to moderate mental retardation and at least one additional handicap. Additional handicapping conditions include cerebral palsy, visual, auditory and/or language impairments and emotional disturbance.

Length of Project Participation: 1984 - 1985 (1 year)

7. Site: Lake View Woods State School
351 E. Gregory
Lee's Summit, MO

Program: Multiply Handicapped Classroom

Responsible Agency: Missouri State Schools for Severely Handicapped

Number of Children: 5

Ages: 5-10 years

School Hours: Monday - Friday, 9:00 - 2:30

Description of Population: elementary school-aged children with severe mental retardation and at least one additional handicapping condition. Additional handicapping conditions include cerebral palsy, visual and/or auditory impairments and emotional disturbance.

Length of Project Participation: 1984 - 1985 (1 year)

8. Site: Crippled Childrens Nursery School
24th at Gillam
Kansas City, MO

Program: Preschool classrooms

Responsible Agency: Crippled Children's Nursery School
Childrens Mercy Hospital

Number of Children: 30

Ages: 2-5 years

School Hours: Monday - Friday, 8:00 - 2:30

Description of Population: preschool-aged children with mild to moderate mental retardation or other handicapping conditions. Additional handicapping conditions include cerebral palsy, spina bifida, visual and/or auditory impairments and various types of orthopedic conditions.

Length of Project Participation: 1985 - 1986 (1 year)

Research Designs

The majority of previous studies involving interventions to train motor behaviors have utilized group designs. The reliance on these designs is one reason this research area has been so underdeveloped. The population of children with multiple sensory and motor impairments is relatively small and so heterogeneous that group designs with their requirements for homogeneous matched samples to demonstrate experimental control are inherently inappropriate. For this reason, single subject research designs have been proposed for utilization with this population of children who are handicapped (Hatcher, 1980; Tawney & Gast, 1984). Single subject research designs have been used widely and with other populations and therapeutic needs (Hersen & Barlow, 1976). Conceptually, these designs follow the same logic for demonstrating cause and effect relations as do group designs (Sidman, 1960), and these designs provide for both internal and external validity (Tawney & Gast, 1984).

Single subject research designs are applicable with a very heterogeneous population because each subject serves as his/her own control. The designs meet ethical standards because they require no control groups who do not receive treatment. The following single subject designs were employed in our studies.

Multiple baseline design. This design (Baer, Wolf, & Risley, 1968) was a time-lagged design composed of a baseline and a treatment phase. It required repeated measures of one behavior across several subjects. Experimental control was demonstrated by introducing the therapeutic technique to each baseline at a different time, and noting the resulting change or absence of change in all baselines. Control was established when there was change only in the baseline in which treatment was applied. All baselines were monitored from the first day to the introduction of the therapeutic technique. When the treatment was introduced it remained in effect for the duration of the study and was monitored continuously. If changes in the level and/or trend occurred each time the treatment was successively introduced, and if baselines to which the treatment was not introduced remained stable, then the experimeters had confidence that the treatment was effective.

Multiple probe design. One type of design, the multiple probe design, was used in the final studies and was especially suited for investigations of this nature. It was particularly useful for skills that reflect the acquisition of a sequence of functionally related prerequisite responses, such as motor skills.

The multiple probe design was proposed by Horner and Baer (1978) to solve a problem inherent in the standard multiple baseline design. A conceptual weakness of any multiple-baseline design are baselines that cannot change at any time, intervention or not, until a prerequisite behavior is learned. Baselines that cannot change are not true baselines and therefore muddle the issue of experimental control (Hersen & Barlow, 1976). The multiple probe techniques featured: (1) an initial baseline probe session conducted on each of the steps in the training sequence; (2) an additional probe session conducted on every step in the training sequence immediately after criterion is reached on any training step; (3) a series of so-called true baseline sessions conducted just before each introduction of the independent variable--a series that increased by at leat one session as each additional step in the sequence is trained (Horner & Baer, 1978). In addition, intermittent probes provided an alternative to continuous baseline measurement, when such measurement during extended multiple baselines might prove reactive, impractical, and/or a strong apriori assumption of stability can be made. It decreased the measurement requirements for the dependent variables which were very time consuming, especially when four to six subjects were participating in the study.

The multiple probe design did not require daily baseline measures across all subjects (as does a multiple baseline design) and thus allowed for more quality and in-depth measures when they were taken. A second reason for using a multiple probe design was related to subject characteristics. For most subjects with severe and multiple handicaps, sudden nonintervention changes in either head erect or sitting behavior are unlikely. Accordingly, baseline probes, scattered over time generally reflected their true motor status prior to intervention. External validity was achieved by replicating the effects across subjects who entered the treatment conditions at varying points in time in accordance with the basic assumptions of multiple probe (or multiple baseline) designs.

Alternating treatment design. The essential feature of this design is the rapid alternation of two or more treatments for a single subject (Barlow & Hayes, 1979). When the experimental question was the comparison of two treatments, there are few alternatives. Furthermore, the testing of two treatments for the same subject within the same time period (i.e., same day) produces an elegant control for most threats to internal validity. Because confounding factors such as time of administration and effects of sequence can be neutralied by counterbalancing effects (e.g., ABBAAB), differences in the individual plots of behavior change corresponding with the treatment should be attributable to the treatment itself, thus allowing the direct comparisons of treatments. This was made possible by rapid condition alternation, which allowed more administrations of the two conditions in a shorter period of time than would be possible with the standard A-B-A design where phases might last weeks or months.

Our research used the alternating treatment design for evaluation of two treatment conditions and treatment and no treatment conditions acoss days.

Covariation probes. The covariation probes (Objective 2) were conceptualized as part of the preceding research designs. The appropriate response covariation probe was administered each time a subject reached a criterion or condition change point within the individual subject experiments that comprised Objective 1. The timing of this administration allowed an assessment of response covariation to be made each time the child showed progress toward acquiring the target skill in a given experiment. These probes allowed us to address the question "What are the effects of treating certain key motor behaviors on the development of other associated skills on the continuum of motor development?".

Generalization probes. Generalization probe trials were administered in several studies to determine the extent to which treatment effects generalized to settings and situations where the child had the opportunity to display emerging motor skills (e.g. head erect, sitting behavior) in a more natural context. This included, for example, measures of sitting behavior while the child was receiving group instruction in the classroom; measures of head erect behavior during free play time. Generalization probe trials were administered at varying points of time across both baseline and treatment conditions. Changes in performance between baseline and treatment conditions suggested the efficacy of the intervention in improving the child's behavior in more natural contexts.

Maintenance probes. Follow-up measures were administered to analyze the durability of treatment effects. These data were collected from 2 to 8 weeks following the conclusion of the individual studies.

Interobserver agreement. Interobserver agreement measures were taken from direct observation of the child. These measures were conducted for a minimum of 50% of the sessions across subjects, conditions and studies.

Measurement System--Dependent Variables

The first stage in the development of sitting and locomotion consists in gaining control of the muscles of the head and neck so that the head may not only be held erect but may compensate for changes in bodily posture (Gesell, 1940). Motor development generally occurs in a cephalocaudal direction, thus the emergence and acquisition of head erect behavior is a prerequisite for succeeding motor milestones. Developmentally, sitting represents a transitional stage between the supine and standing postures; a posture maintained against gravity, it combines flexion of the hips with extension of the back (Gesell, 1940).

The sequence as it relates to the motor area is primarily based on the work of Gesell (Gesell, Thompson, & Armatruda, 1934). The sequence and rate of development proposed by Gesell and his colleagues and later expanded through the work of Bayley (1933), Cattell (1940) and Frankenburg and Dodds (1969) provide the basis for the measurement of motor skills in standardized and nonstandardized instruments. The acquisition of head erect behavior is described by one or two steps in the majority of instruments. Similarly sitting is described as a trend from a uniformly round back to straight alignment of the trunk. The limitations of traditional assessment instruments in documenting incremental changes in the motor development of children with handicapping conditions were discussed in the previous literature review. The following operational definitions of head erect, upper extremity weight bearing, sitting, reach and grasp developed in our previous research efforts are presented below. Included also are measurement procedures, selection criteria, and potential covarying behaviors.

Head erect and upper extremity weight bearing. The head was lifted or considered to be in the erect position when no part of the head or neck (chin to clavicle) was touching the supporting surface, nor resting on or touching the child's arms which are in contact with the supporting surface.

Head lift without arm support. The head was lifted and an elbow angle of less than 90 degrees was present.

Head lift with forearm props. The head was lifted and an elbow angle greater than or equal to 90 degrees was present.

Head lift with extended arm support. The head was lifted and no part of the arm was touching the supporting surface. Only the hands were in contact with the supporting surface.

Combinations of the above definitions were possible. One arm may have fit one definition and the other arm may have fit a different definition. These combinations were presented in the abbreviation code on the data sheet.

Measurement procedure. Frequency of head lifts and cumulative duration of head erect were recorded during each session. In addition, frequency and topography of upper extremity weight bearing responses (e.g., arm positions) were also recorded. A session consisted of one trial 3 minutes in length during vibration or following rotary vestibular stimulation, or 9 minutes in length during inversion. Appendix A contains a complete description of the head erect measurement procedure including data sheets.

Selection criteria. Selection criterion included the inability of the subject to maintain head erect behavior for a cumulative duration of 60 seconds in a 3 minute time sample.

Potential covarying behaviors. Visual fixation and upper extremity weight bearing responses were identified as potential covarying behaviors for head erect behavior. Covariation probes for these behaviors were conducted using the quantitative assessments developed by the investigators (c.f. Guess, Rues, Warren, & Lyon, 1980).

Sitting. The subject's back posture relative to the trunk's deviation from the vertical plane, as viewed from the side through the plexiglass section device, was used to record the erectness of the sitting behavior. Positioning of the subject and equipment are showed in Figure 4.

Measurement procedure. The measurement session consisted of a 3-minute observation period that was marked off into 36 time checks at 5-s intervals. The numbered section (1-6) in which an adhesive marker on the subject's shoulder was observed was recorded at each of the 36 time checks. A pre-recorded audio tape cued the observer at each of the 5-s intervals. Each session consisted of one trial 3 minutes in length. Appendix B contains a complete description of the sitting measurement procedure.

Potential covarying behaviors. Postural fixation and protective extension responses were identified as potential covarying behaviors for sitting behavior. Covariation probes were conducted using the quantitative assessments developed by the investigators (c.f. Guess, Rues, Warren, & Lyon, 1980).

Selection criterion. The criterion for subject selection was the inability of the child to maintain a cumulative duration of independent sitting for 60 seconds, but the ability to maintain supported sitting (with external support provided at the pelvis) for a cumulative duration of 100 seconds or more, as measured in a 3 minute time sample.

Reach and grasp. The topography of reach and grasp descriptors included:

No movement. From the child's starting position, no obvious change in the angles of the elbow or shoulder joints (less than 15°) was observed in the 2 minute stimulus presentation time limit. Movement of the fingers and/or wrist without accompanying change in the angle of the

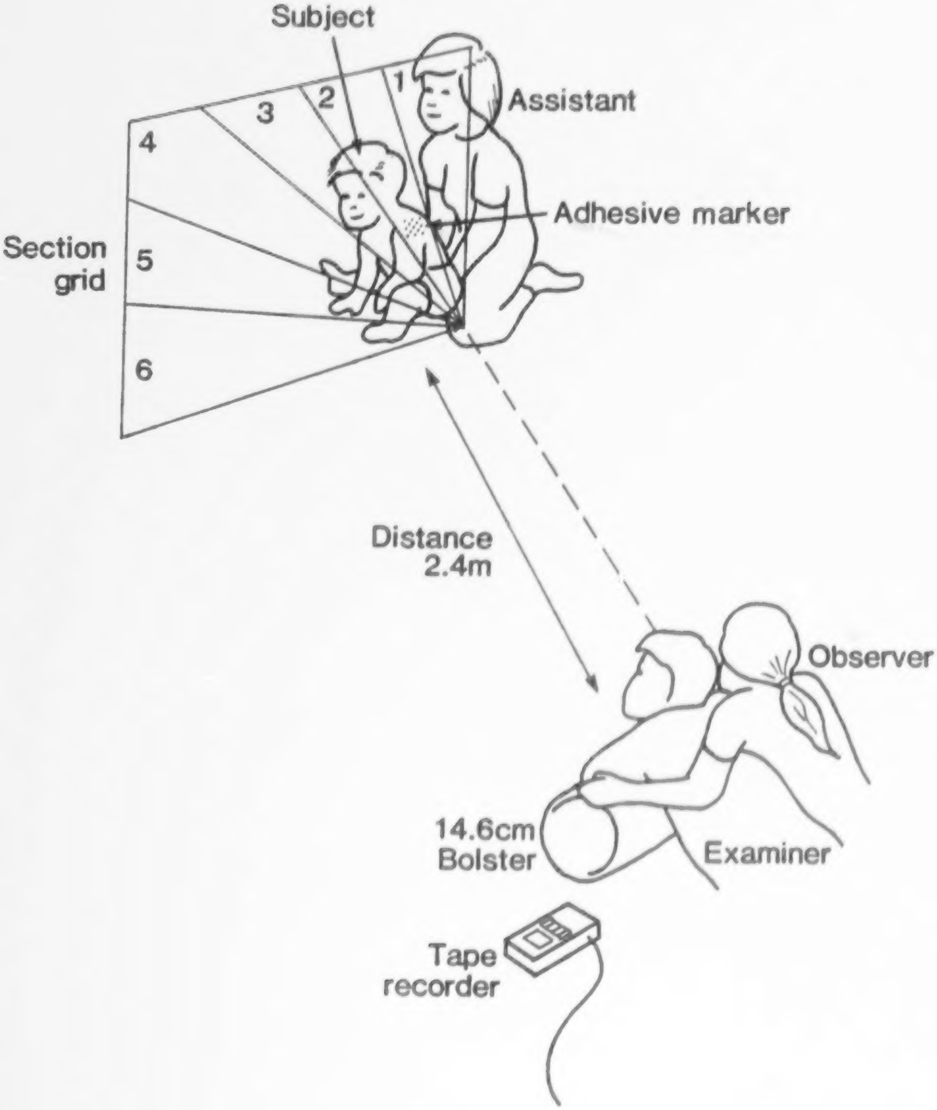


Figure 4. Sitting Measurement for Cumulative Duration of Erect Sitting.

elbow and/or shoulder was considered "no movement". The right and left arms were scored separately. When "no movement" was scored, no other box on the data sheet was scored.

Movement-no contact. From the child's starting position, an obvious change in the angles of the elbow and/or shoulder joints (15° or more) was observed during the 2 minute stimulus presentation time limit. The child did not touch the stimulus material with any part of the hand (palm, fingers, back, side, etc.). The right and left arms were observed and scored separately. When "movement-no contact" was checked, the type of movement used, "direct or indirect" for that hand was also recorded.

Contact. From the starting position, an obvious change in the angles of the elbow and/or shoulder joints was observed (15^0 or more) resulting in contact of any part of the child's hand or arm (palm, fingers, thumb, back, side, etc.) with the stimulus object. The right and left arms were scored separately. If "contact" was checked, the type of movement (direct or indirect) and whether the movement was "on or off" the testing surface was also recorded for that arm.

Direct. From the starting position, the child's arm and hand followed the most direct (imaginary straight line) path to the stimulus object without any movement varying from this path during the stimulus presentation. Direct was checked for "movement without contact" or "contact". The right and left arms were scored separately.

Indirect. From the starting position, the child's arm and hand deviated from the most direct path (imaginary straight line) from the starting position of the hand to the stimulus object. This movement was circuitous, composed of lateral swipes, or jerky and unsmooth in nature. "Indirect" was checked when there was either "movement without contact" or "contact".

On surface. From the starting position, the child's hand and/or arm touched the testing surface (tray) at any point during the stimulus presentation. Touching the hand and/or arm to the testing surface simultaneously when making contact with the toy was not considered to be "on" the testing surface. This code was checked only when contact was made. The right and left arms were scored separately.

Off surface. From the starting position, the child's hand and arm did not touch the testing surface during the stimulus presentation. However, the hand and/or arm contacted the tray upon simultaneous contact with the stimulus object. This code was checked only if contact was made. The right and left arms were scored separately.

Grasp. Any pattern of grasp was acceptable providing the stimulus object was grasped and held off the testing surface. The object may be grasped off the testing surface momentarily, then returned to the surface. Grasping the stimulus, but not lifting it from the surface was not considered in this definition of grasp.

Measurement procedure. The subject's reach and grasp were measured with the child positioned in an upright, adaptive seating device, equipped with a tray. The topography of each reaching response was recorded for each six stimulus position presentations. The occurrence/nonoccurrence for grasp was recorded subsequent to the reach measurement. The duration of each of the six stimulus positions was limited to a 2 minute observation period. Time (in seconds) was recorded when contact for reach and moment of grasp. Positioning of the subject and equipment are shown in Figure 5.

The measurement session consisted of a maximum of 2 minute observation period for each of six stimulus positions. Each session consisted of six trials for different stimulus positions.

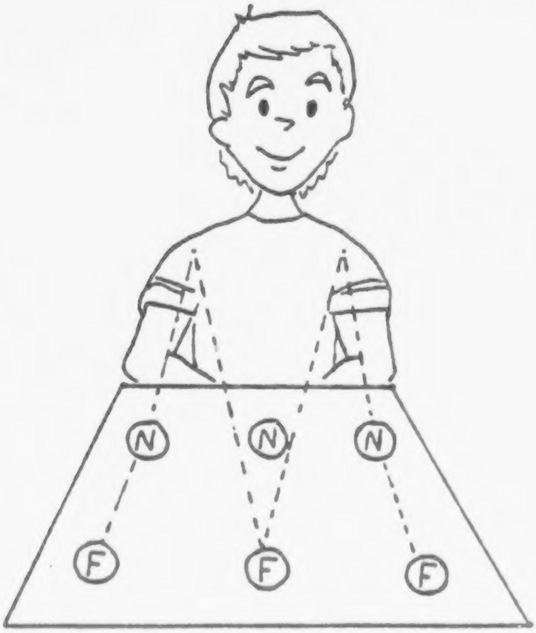


Figure 5. Positioning of subject and equipment for reach and grasp measurement.

The timing began as soon as the stimulus was placed on the stimulus position. The session continued until contact was made or the 2 minute time limit was exceeded. If contact was made but the object was not grasped the time was noted and the stopwatch restarted and the subject was given the remainder of the 2 minutes to grasp the object. The exact time was rounded within one second and recorded on the data sheet.

Selection criterion. Selection criterion was based on identified deficits in reach-grasp behavior via the child's Individual Education Plan.

Therapeutic Techniques--Independent Variables

Although therapists employ a number of neurophysical techniques in habilitative efforts with individuals who are handicapped, the following techniques were chosen because of their use across several treatment approaches (Hagbarth & Eklund, 1969; Heininger & Randolph, 1981). Wider impact of the research results was thereby anticipated than would have occurred with similar studies on interesting but obscure techniques.

Vibration. Vibration used for therapeutic purposes was a high frequency, low amplitude vibratory stimulus applied directly and locally to a selected muscle and/or tendon. Three motor effects are observed following vibration. The vibrated muscle actively contracts. This sustained contraction is known as the tonic vibratory reflex (TVR). The excitability of motor neurons innervating the antagonist muscles are depressed via reciprocal inhibition. During vibration, the monosynaptic stretch reflexes are suppressed.

Method. The muscle belly or tendon of the selected muscle(s) was vibrated with a hand-held electric vibrator with a frequency of 65-100 Hertz and an amplitude of 1.5 millimeter. Duration of vibration did not exceed 2 minutes to avoid skin friction. Guidelines for the site of application are included in the individual studies as the site varied dependent on the targeted motor behavior.

Potential adverse reactions. Possible side effects include aggravation rather than alleviation of clinical symptoms of individuals with cerebellar disease. Children with identified cerebellar dysfunction were not included as subjects in the vibration studies.

Vestibular stimulation. Vestibular stimulation results from movement as it is detected by the vestibular system located in the middle ear. Movement includes rotary acceleration, linear acceleration or the natural gravitational pull. According to Parker (1977), the vestibular system responds to the initiation and cessation of rotary and linear movements; the more dramatic the change, the greater the stimulation to the semicircular canals. Rotary movement is produced by spinning or rotating with linear movement produced by rocking or bouncing motions. Response to gravitational pull occurs when gravitational force is displaced anteriorly, posteriorly or laterally.

Acceleration techniques utilized in previous research on rotary movement (Kantner, Clar, Allen & Chase, 1976; Clark, Kreutzberg & Chee, 1977; Chee et al, 1978; and Ottenbacher et al, 1984) assisted us in defining the parameters of the stimulation used in this research.

Several methods of vestibular stimulation were employed in this research. Due to the characteristics of our subject population, the methodology reflected a conservative approach in relation to the total duration of vestibular stimulation per study. These methods, which denote changes in the duration of stimulation, are presented sequentially below. The positions employed were selected to maximize stimulation of the horizontal, posterior and anterior canals (Chee, et al., 1978).

Method A. A session in Method A consisted of 4 minutes of spinning in a vestibular box. The subject was positioned and secured in a tumble form chair (premolded plastic chair) in the vestibular box (Figure 6). The subject was positioned in upright sitting for 2 minutes, 1 minute clockwise (CW) and 1 minute counter clockwise (CCW) with the head flexed at 30 degrees. This procedure placed the horizontal semicircular canals in the horizontal plane. The subject was the positioned in either the right or left sidelying position (i.e. sidelying position was alternated each session) to place one anterior and the opposite posterior semicircular canals in the horizontal plane for 2 minutes of spinning, 1 minute CW and 1 minute CCW. Each minute consisted of a rapid (1-2s) angular acceleration, a 1-minute period of constant velocity at 180°/second, followed by a sudden stop in less than 1 second. A 10 second period of no movement elapsed between CW and CCW spins and a 30 second period between position changes (i.e. sitting to sidelying). Table 1 delineates the positions and durations of vestibular stimulation employed.

After the final spin, measures were taken on the dependent variable. A prerecorded timing tape provided auditory cues for each step in the sequence of stimulation.

Method B. A session in Method B consisted of spinning in the vestibular box. Method B followed the same sequence of spinning as described for Method A, with the exception of the addition of 2 minutes of spinning. Those 2 minutes were inserted by incorporating both the right and left sidelying positions in each session rather than alternating them. The subject was positioned in right sidelying for 2 spins (CW and

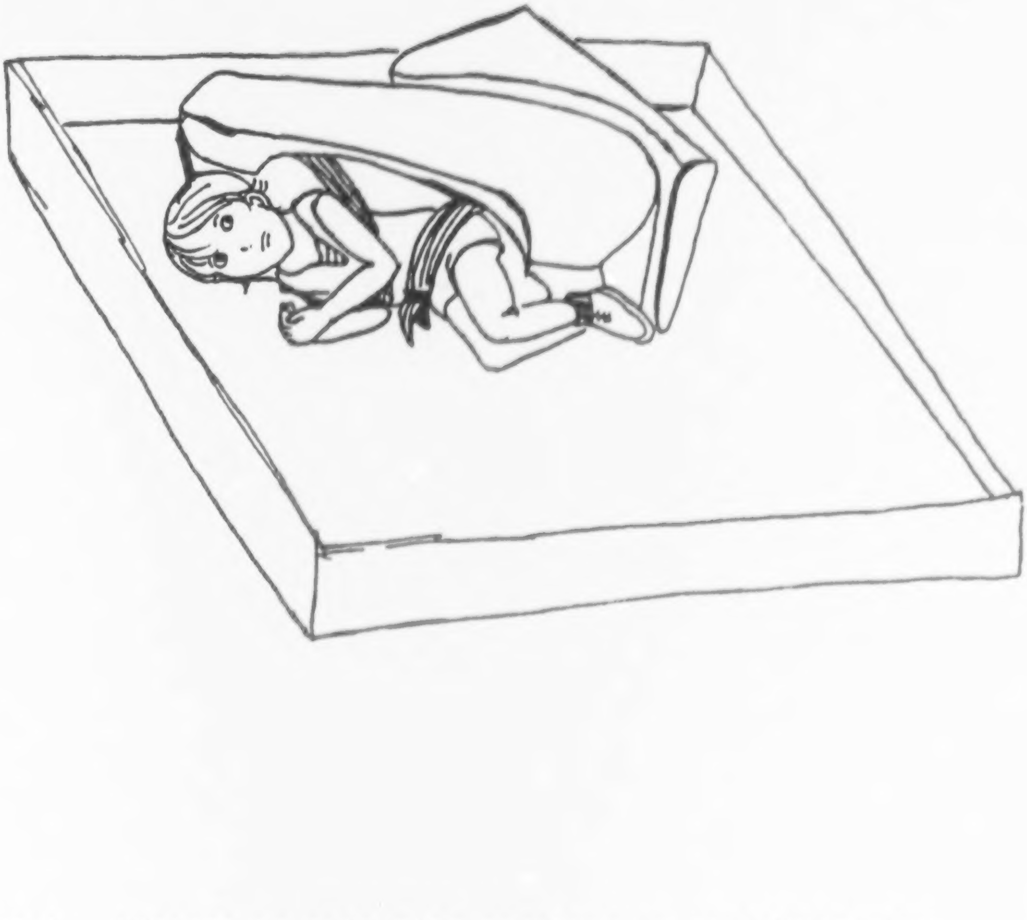


Figure 6. Subject in sidelying position in vestibular box.

Table 1

Spinning Sequence for Vestibular Stimulation-Method A (4 minutes)

Subject Position	Spin Direction	Duration of Stimulation
Upright sitting	1. Clockwise*	1 minute
	2. Counter-clockwise	1 minute
Right or left sidelying	1. Clockwise	1 minute
	2. Counter-clockwise	1 minute
	Total	4 minutes

*Each spin consisted of: (a) a 1-2 second acceleration, (b) a 1-minute period of constant velocity at 180°/second (30 RPM), (c) an impulsive stop in less than 1 second, and (d) a 10-second period of no movement

CCW) and than repositioned in left sidelying for 2 spins. A 20-30 second period of no movement elapsed between spins and position changes. Table 2 includes the positions and durations of vestibular stimulation employed.

Method C. Three phases of vestibular stimulation were employed: Phase 1 produced a cumulative duration of 8 minutes of vestibular stimulation; Phase 2 produced a cumulative duration of 8 minutes of vestibular stimulation with the addition of the supine position; and Phase 3 produced a cumulative duration of 10 minutes of vestibular stimulation. Phases 2 and 3 were implemented for those subjects that did not demonstrate an increase or maintain an increase in the target behavior of head erect behavior. The change from Phase 1 to Phase 2 to Phase 3 was determined through an analysis of the graphed data. The specific procedures used for each spin in the three phases promoted maximum stimulation of the horizontal, posterior, and anterior semi-circular canals. Table 3 presents an outline of the intervention procedures for the three phases. Only one subject did not receive Phases 2 and 3 due to respiratory problems which were exacerbated in the supine position.

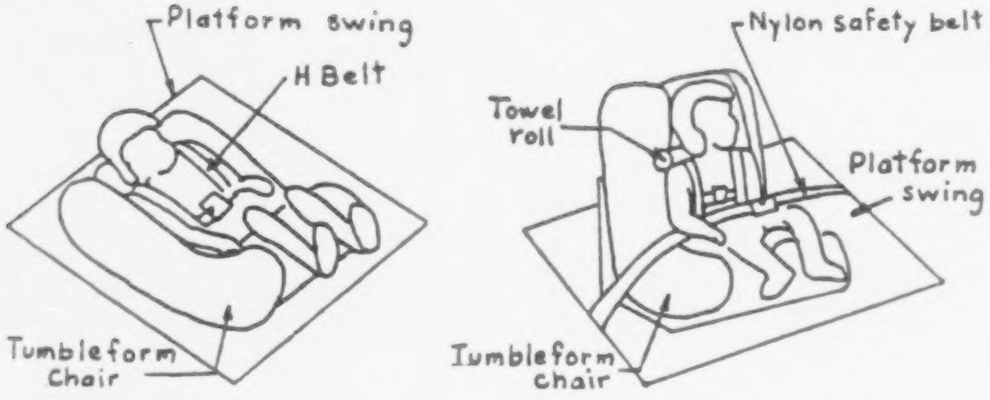
Phase 1. The subject was initially positioned and secured in upright sitting on the platform swing (Figure 7). The examiner began the timing tape and manually spun the swing in a CW direction, creating an acceleration period of 1-2 seconds. The spinning was maintained at a constant velocity (one spin every 2 seconds) for 1 minute by the examiner who paced the spinning rate according to the 2-second intervals marked off on the timing tape. The 1-minute period of constant velocity was followed by an impulsive stop, in less than 1 second, and a 10-second period of no movement. The swing, with the subject remaining in upright

Table 2

Spinning Sequence for Vestibular Stimulation-Method B (6 minutes)

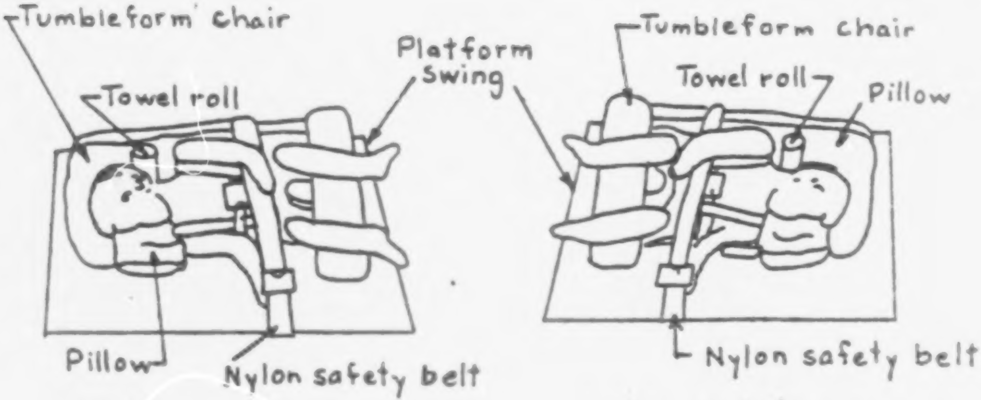
Subject Position	Spin Direction	Duration of Stimulation
Left Sidelying	1. Clockwise*	1 minute
	2. Counter-clockwise	1 minute
Right Sidelying	1. Clockwise	1 minute
	2. Counter-clockwise	1 minute
Upright Sitting	1. Clockwise	1 minute
	2. Counter-clockwise	1 minute
	Total	6 minutes

*Each spin consisted of: (a) a 1-2 second acceleration, (b) a 1-minute period of constant velocity at 180°/second (30 RPM), (c) an impulsive stop in less than 1 second, and (d) a 10-second period of no movement



Supine Position

Upright Sitting



Right Sidelying

Left Sidelying

Figure 7. Positioning for vestibular stimulation in the supine, upright, right, and left sidelying position (Method C).

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sitting, was then spun in the CCW direction following the same pattern as delineated for the CW direction. The second minute period of rotation was followed by an impulsive stop in less than 1 second and a 10-second period of no movement. The procedures for spinning in the CW and CCW directions were repeated. After the 10-second rest period in the CCW direction, the subject was repositioned and secured in right sidelying and spun in both the CW and CCW directions following the procedures described above. The same spinning sequence was then repeated with the subject positioned and secured in left sidelying. This procedure produced a cumulative duration of 8 minutes of vestibular stimulation.

Phase 2. During this phase, the supine position was substituted for the second series of spins in upright sitting. The subject was positioned in upright sitting and spun in a CW direction followed by a CCW direction as previously described. The subject was then positioned in supine, rather than remaining in the upright position, and was spun in the CW direction and then in the CCW direction. This was followed by positioning in right and then left sidelying according to the sequence delineated for Phase 1. This procedure resulted in a cumulative duration of 8 minutes of vestibular stimulation.

Phase 3. The procedures for Phase 3 followed the same sequence of spins as described for Phase 1, with the addition of the supine position following the two series of spins in upright sitting. The subject was positioned in the supine position and was spun in the CW direction and then in the CCW direction. The subject was then positioned in right sidelying and then repositioned in left sidelying according to the sequence delineated for Phase 1. This procedure resulted in a cumulative duration of 10 minutes of vestibular stimulation. After the final

10-second rest period for each session, measures were taken on the dependent variable. Table 3 includes the positions and durations of vestibular stimulation employed.

Method D. Two phases of vestibular stimulation were employed. Phase 1 provided a total duration of 6 minutes of vestibular stimulation, and Phase 2 provided a total duration of 8 minutes of vestibular stimulation. Phase 1 was implemented for all subjects. Phase 2 was implemented for those subjects who did not demonstrate a substantial change in the dependent variables (head erect and sitting behavior) with 6 minutes of vestibular stimulation. The change from Phase 1 to Phase 2 was determined through an analysis of the graphed data. Table 4 presents an outline of the intervention phases.

Phase 1. A session in Phase 1 consisted of 6 minutes of spinning on the platform swing in a brightly lit room. The subject was positioned and secured in the tumbleform chair on the platform swing. The subject was positioned in upright sitting for 2 minutes, 1 minute clockwise (CW) and 1 minute counterclockwise (CCW), with the head flexed at about 30 degrees. The subject was then positioned in right sidelying for 2 minutes of spinning, 1 minute CW and 1 minute CCW. The subject was then shifted to left sidelying, for 2 minutes of spinning, 1 minute CW and 1 minute CCW. Each minute consisted of a rapid (1-2s) angular acceleration, a 1-minute period of constant velocity of 180 degrees/second (30 rpm), followed by a sudden stop in less than 1 s, and a 1-minute period of no movement. Figure 8 presents the positioning of the subject for intervention.

Phase 2. A session in Phase 2 consisted of 8 minutes of spinning on the platform swing in a brightly lit room. Phase 2 followed the same

Table 3

Spinning Sequence for Vestibular Stimulation during Phase 1, Phase 2, and Phase 3 of Intervention - Method C

Phase	Subject Position	Spin Direction	Duration of Stimulation
1	Upright Sitting	1. Clockwise*	1 minute
		2. Counterclockwise	1 minute
		3. Clockwise	1 minute
		4. Counterclockwise	1 minute
	Right Sidelying	1. Clockwise	1 minute
		2. Counterclockwise	1 minute
	Left Sidelying	1. Clockwise	1 minute
		2. Counterclockwise	1 minute
		Total	8 minutes
2	Upright Sitting	1. Clockwise	1 minute
		2. Counterclockwise	1 minute
	Supine	1. Clockwise	1 minute
		2. Counterclockwise	1 minute
	Right Sidelying	1. Clockwise	1 minute
		2. Counterclockwise	1 minute
	Left Sidelying	1. Clockwise	1 minute
		2. Counterclockwise	1 minute
		Total	8 minutes
3	Upright Sitting	1. Clockwise	1 minute
		2. Counterclockwise	1 minute
		3. Clockwise	1 minute
		4. Counterclockwise	1 minute
	Supine	1. Clockwise	1 minute
		2. Counterclockwise	1 minute
	Right Sidelying	1. Clockwise	1 minute
		2. Counterclockwise	1 minute
	Left Sidelying	1. Clockwise	1 minute
		2. Counterclockwise	1 minute
		Total	10 minutes

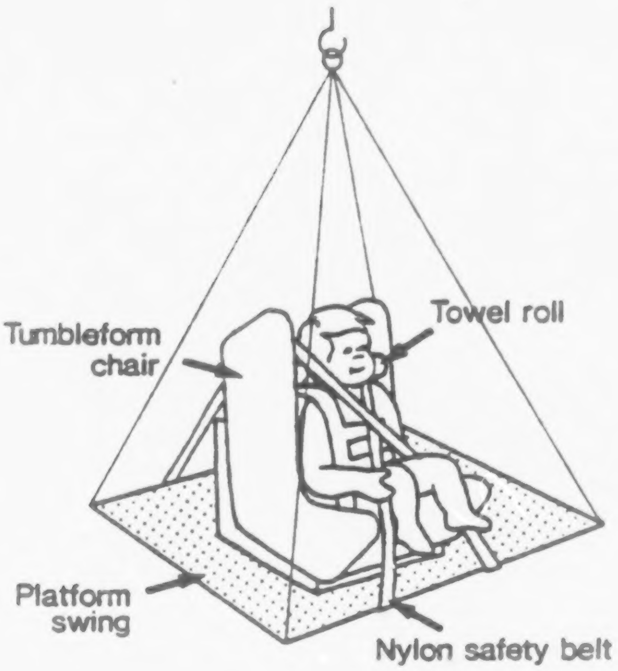
*Each spin consisted of: (a) a 1-2 second acceleration, (b) a 1-minute period of constant velocity at 180°/second (30 RPM), (c) an impulsive stop in less than 1 second, and (d) a 10-second period of no movement

Table 4

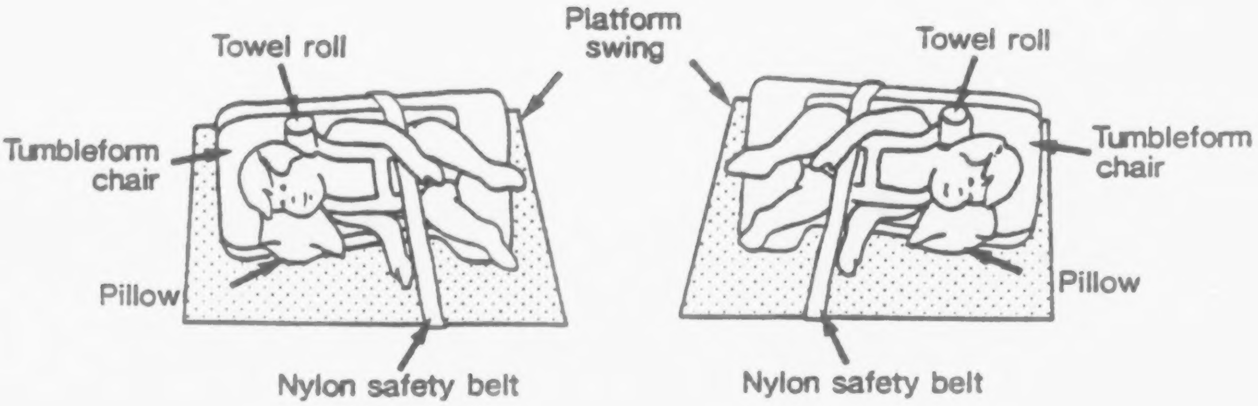
Spinning Sequence for Vestibular Stimulation During Level One and Level Two of Intervention

Level	Subject Position	Spin Direction	Duration of Stimulation
One	Upright Sitting	1. Clockwise* 2. Counter-Clockwise	
	Right Sidelying	1. Clockwise 2. Counter-Clockwise	
	Left Sidelying	1. Clockwise 2. Counter-Clockwise	6 minutes
Two	Upright Sitting	1. Clockwise 2. Counter-Clockwise 3. Clockwise 4. Counter-Clockwise	
	Right Sidelying	1. Clockwise 2. Counter-Clockwise	
	Left Sidelying	1. Clockwise 2. Counter-Clockwise	8 minutes

*Each spin consisted of: (a) a 1-2 second acceleration, (b) a 1-minute period of constant velocity at 180°/second (30 RPM), (c) an impulsive stop in less than 1 second, and (d) a 10-second period of no movement



a) Upright Sitting



b) Right Sidelying

c) Left Sidelying

Figure 8. Positioning of subject for rotary vestibular stimulation in a) upright sitting, b) right sidelying and c) left sidelying positions.

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sequence of spinning as described for Phase 1, with the exception of the addition of 2 minutes of spinning. These 2 minutes were inserted into the spinning sequence immediately following the initial two spins (CW and CCW) in the upright sitting position. The subject remained in the upright sitting position and was spun an additional two times, once CW and once CCW. The subject was then positioned in right sidelying and repositioned in left sidelying, according to the sequence delineated for Phase 1.

After the final 1-minute rest period for each session, measures were taken on the dependent variable. A prerecorded timing tape provided auditory cues for each step in the sequence of stimulation.

Potential Adverse Reactions. Possible side effects to this type of stimulation include dizziness, nausea, sweating, hyperventilation, vomiting, and an increase or decrease in the occurrence of seizures in seizure prone children. The child's response to the stimulation was monitored throughout each session and if any of the above side effects were noted the stimulation was stopped and the legal guardian notified. Continuation in the study was determined through consultation with the child's legal guardians and physicians (e.g., pediatrician/family practitioner and/or pediatric neurologist).

Inversion. Inversion occurs when a person's head is placed lower than the trunk of his or her body. Vestibular sensory input is related either to motion or position of the head in relation to the force of gravity. The position portion of the vestibular system may be activated in treatment by placing the individual in the inverted position. During inversion the anterior canals are the components of the vestibular system that are stimulated. Impulses from these canals travel to the vestibular nuclei in the brainstem which send messages to the cervical and thoracic muscles to facilitate extension of the neck and trunk (Mountcastle, 1968).

There were no published investigations of the inversion procedure to assist us in defining the parameters of this intervention. Our studies investigated the effects of a dynamic and static form of inversion. The duration of inversion resulted from piloting the procedure across subjects to determine tolerance and endurance for the position.

Method A. A session in Method A consisted of rolling the subject in the prone position on a carpeted barrel from a starting point of 0 degrees on the grid to a point of inversion of 60 degrees from vertical within approximately 10 seconds (Figures 9 and 10). At this point, the subject's head was lower than his/her feet. The barrel and child were maintained at 60 degrees from vertical for 30 seconds. The child and barrel were rolled back slowly within 10 seconds to the 0 degree mark. This procedure was repeated in sequence 12-times producing a cumulative duration of 6 minutes of inversion. Following the inversion the child was placed prone on the floor and the dependent variable (i.e. head erect) was measured.

Method B. The intervention procedure consists of placing the child in the inverted position on the inversion board at a 60 degree angle from the vertical axis for 9 minutes. A cushioned board (.78 m x .75m x .37m x 1m) was built to position the child during baseline horizontal position or lowered to a 60 degree angle from the vertical axis (Figure 11).

Measurement of the dependent variable (i.e. head erect) occurred during the 9 minutes that the child was inverted.

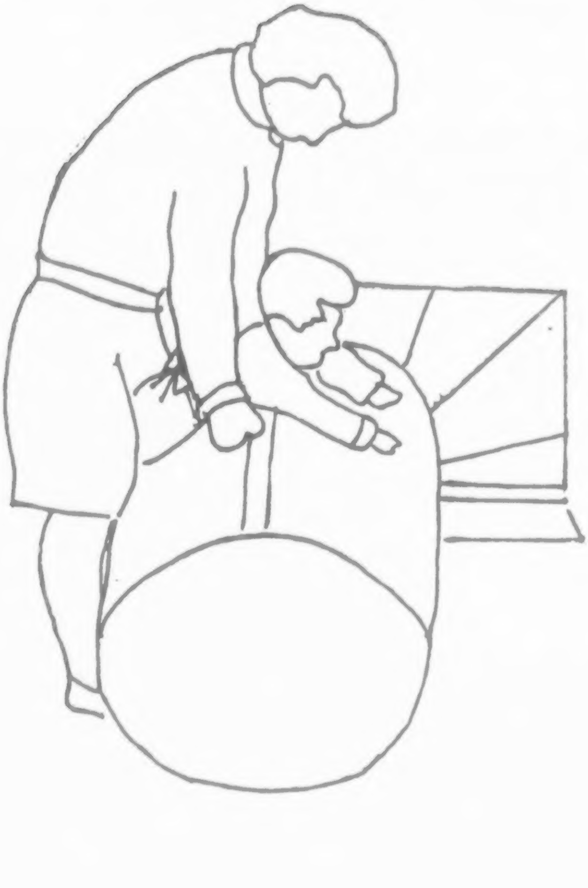


Figure 9. Subject in prone starting position for inversion (Method A).

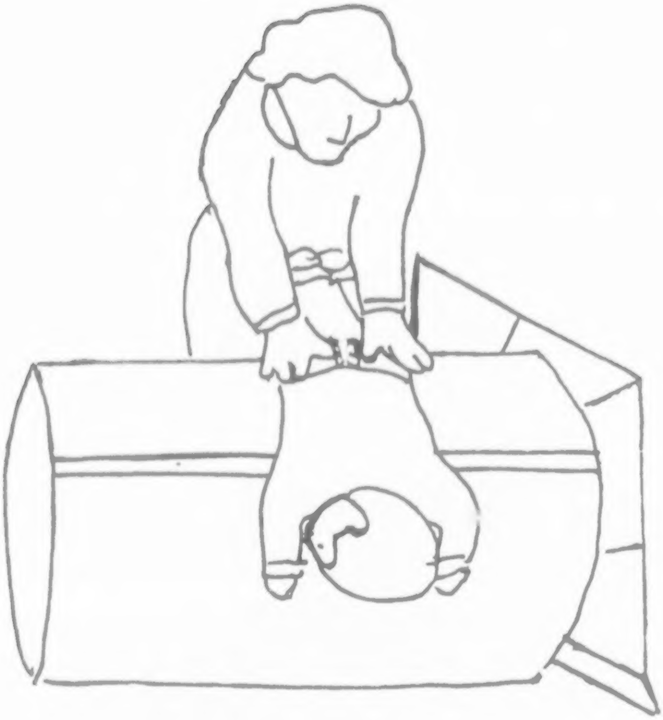
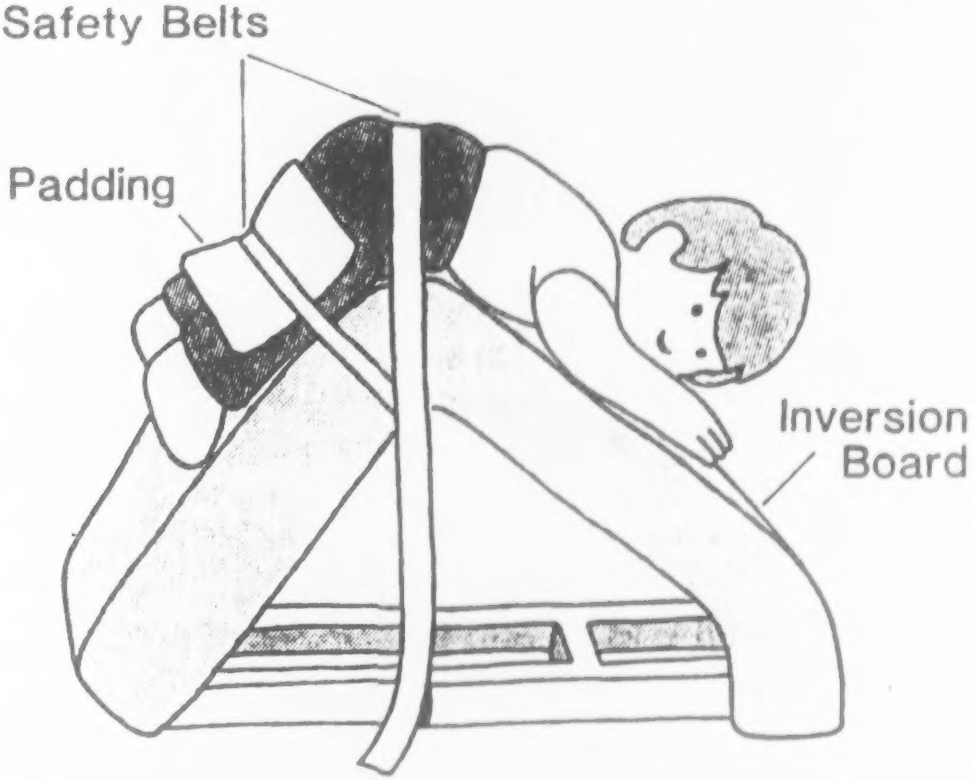


Figure 10. Subject in the inverted position(Method A).



Angle of inversion 60° from vertical axis.

Figure 11. Subject on inversion board (Method B).

Potential adverse reactions. Possible side effects from this type of stimulation include perspiring, yawning, and facial flushing. The child's response to the stimulation was monitored throughout each session and if any of the above side effects were noted the stimulation was stopped and the legal guardian notified. In addition, subjects' blood pressure were monitored intermittently across baseline and intervention conditions with a portable sphygmomanometer with an infant cuff and a Doppler instrument. The legal guardian was notified if any changes in blood pressure were recorded. Continuation in the study was determined through consultation with the child's legal guardian and physicians.

RESULTS AND DISCUSSION

Objective 1 was accomplished through a series of 13 single subject designs conducted over a 3 year period. Those experiments investigated the effects of vibration, vestibular stimulation, and inversion on head erect and sitting behaviors. The probes necessary to accomplish Objective 2 were conducted in conjunction with the experiments in Objective 1. Each experiment included 3 to 4 subjects, each acting as his or her own control. The majority of the studies took from 4-6 months to complete. The length of the individual studies was longer than originally anticipated primarily due to frequent absences of subjects for health reasons.

Frequent absences combined with the lack of data on the basic effects of the therapeutic techniques resulted in a deviation from our original research plan. The proposed plan for Year 1 included a series of studies to investigate the basic effects of vibration, vestibular stimulation, and inversion on basic motor behaviors. During Year 2, frequency of application studies were to be conducted. At the conclusion of Year 1, we realized that the studies completed did not thoroughly address the basic effects questions. The two frequency studies in progress at that time were yielding inconclusive data due to the frequent illnesses of subjects. More imporantly, we recognized the need to systematically address the generalization and maintenance of treatment effects. Those were issues which were more appropriately addressed prior to frequency of application studies. The project plan submitted and approved for Year 2 reflected this change in emphasis.

The remainder of this section summarizes the results of the individual studies conducted across the three therapeutic techniques. Studies related to each technique are presented sequentially followed by an integrated summary addressing the research questions ennumerated under Objectives 1 and 2.

Vibration

Six studies were completed investigating the effects of vibration on basic motor behaviors. The dependent variables were: head erect - 2 studies; upper extremity weight bearing - 1 study; and sitting - 3 studies. Interobserver agreement for the dependent variables was acceptable in each of the 6 studies.

Effects of vibration on the acquisition of head erect behavior in prone: Study 1. A multiple baseline design across subjects was used to assess the effect of vibratory stimulation on the acquisition of head erect behavior in prone of preschool children with severe multiple handicaps. Two children with spastic quadriparesis and one child with hypotonia participated as subjects (Table 5). Frequency of head lifts and cumulative duration of head erect behavior were recorded during a 3 minute session with the subjects positioned in prone over a wedge. Following baseline observations, vibration was applied to the neck and upper back extensors for the first two minutes of each intervention session. In addition, EMG activity was recorded at least once during the baseline and intervention conditions. Results of the study demonstrated an increase in head erect behavior across subjects and an accompanying increase in EMG activity during vibration (Figure 12). The diversity of motoric handicapping conditions appeared to have no effect on the benefits received from vibration.

Effects of the frequency of vibration application on the acquisition of head erect behavior in prone: Study 2. This study utilized an

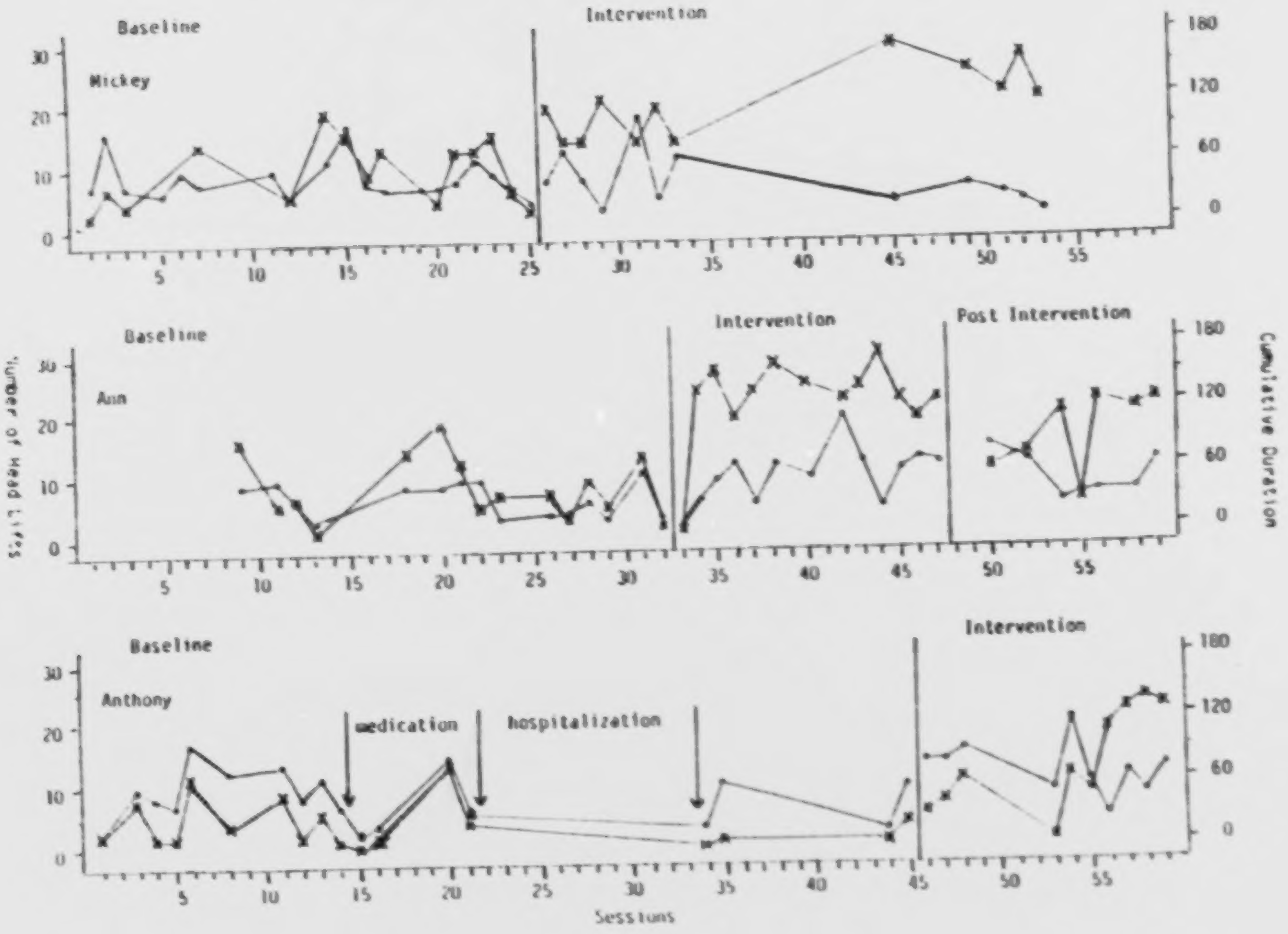


Figure 12. Frequency of Head Lifts and Cumulative Duration of Head Erect
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Table 5

Characteristics of Three Subjects Included in Study 1

CHARACTERISTICS	SUBJECTS		
	1	2	3
Sex	M	F	M
Age	2½ years	3 years	1½ years
Diagnosis	shunted spastic quadriplegic cerebral palsy	multiple congenital anamolies, microcephalic	spastic quadriplegic cerebral palsy
Postural Tone	increased tone in neck, trunk and extremities	hypotonic in neck, trunk, and extremities	increased tone in neck, trunk, and extremities
History of Seizures	controlled with medication	none	controlled with medication
Gross Motor	2 months	2-3 months	2-3 months
Fine Motor	2 months	5-6 months	2-3 months
Cognitive Level	4 months	5-6 months	2-3 months
Mode of Communication	no formal mode	no formal mode	no formal mode
Adaptive Devices	none	none	none

alternating treatment design to investigate the effects of the frequency of vibration application on the acquisition of head erect behavior in the prone position in 4 preschool children with multiple handicaps (Table 6). Frequency of head lifts and cumulative duration of head erect behavior were recorded during a 3 minute session with the child positioned prone over a wedge. Intervention consisted of vibration applied to the paraspinal neck and back extensor muscles for the first 2 minutes of each session. Intervention sessions randomly alternated between treatment once and twice a day, to assess the effects of the frequency of vibration application. Results of the study demonstrated no statistically significant differences in performance between treatment conditions (Table 7). Probes for covarying behaviors (i.e., upper extremity weightbearing and visual fixation) were conducted across subjects and conditions with no effects noted.

Effects of vibration on the acquisition of upper extremity weight hearing: Study 3. A multiple baseline design across subjects was used to assess the effects of vibratory stimulation on the acquisition of upper extremity weight bearing in prone in preschool children with multiple handicaps. Two children with spastic quadriparesis and one child with athetosis served as subjects (Table 8). Occurrence of all arm positions of upper extremity weight bearing and cumulative duration of forearm props were recorded in a 3 minute session across conditions. Vibration was applied to the paraspinal muscles of the back from the base of the neck to the base of the lumbar spine for one minute and to the elbow extensors for another minute on 2 subjects. On the third subject, vibration was applied from the base of the neck to the level of the inferior angle of the scapula for one minute and to the elbow flexors for another minute.

Table 6

Characteristics of Four Children Included in Study 2

Characteristics	Subjects			
	1	2	3	4
Sex	F	M	F	F
Age	1½ years	1½ years	4½ years	3½ years
Diagnosis	spastic quadriplegic cerebral palsy, occipital encephalocele	spastic quadriplegic cerebral palsy, visually impaired	spastic quadriplegic cerebral palsy	athetoid cerebral palsy, visually and hearing impaired
Postural Tone	increased tone in extremities, decreased tone in neck and trunk	increased tone in all extremities, neck, and trunk	increased tone in neck, trunk, and all extremities	fluctuating tone in neck, trunk, and all extremities
History of Seizures	controlled with medication	controlled with medication	controlled with medication	controlled with medication
Gross Motor Level	3-4 months	3 months	2-3 months	2-3 months
Fine Motor Level	3 months	4-6 months	2-4 months	2-3 months
Cognitive Level	2-4 months	4-6 months	5-6 months	4-6 months
Mode of Communication	no formal mode	no formal mode	no formal mode	no formal mode
Adaptive Devices	none	none	none	bilateral hearing aids, corrective glasses

Table 7

Mean Frequency and Cumulatve Duration of Head Erect Behavior During Intervention Sessions

	1x day			1st session of 2x day			2nd session of 2x day		
Subjects	freq.	c.d.	%	freq.	c.d.	%	freq.	c.d.	%
Kristie	4	6	3%	4	4	2%	2	2	1%
Sally	10	139	77%	12	120	67%	12	112	62%
Kyle	15	87	48%	14	89	49%	15	81	45%
Lucy	7	46	26%	7	39	22%	8	55	30%

Table 8

Characteristics of Three Subjects Included in Study 3

CHARACTERISTICS	STUDY		
	1	2	3
Sex	M	M	M
Age	2½ years	3½ years	4½ years
Diagnosis	athetoid cerebral palsy, severe bilateral hearing loss	spastic quadriplegic cerebral palsy	spastic quadriplegic cerebral palsy
Postural Tone	fluctuating tone in neck, trunk, and all extremities	increased tone in neck, trunk, and all extremities	increased tone in neck, trunk, and all extremities
History of Seizures	none	controlled with medication	none
Gross Motor Level	6-9 months	9-18 months	4-6 months
Fine Motor Level	6-12 months	6-9 months	4-6 months
Cognitive Level	12-18 months	6-10 months	8-12 months
Mode of Communication	sign language	no formal mode	no formal mode
Adaptive Devices	hearing aid	none	none

Results of the study demonstrated an increase in duration of bilateral forearm props for one subject; an increase in bilateral responses for the second subject; and an increase in frequency of arm positions for the third subject. Probes for covarying behaviors (i.e., reach and come-to-sit) were conducted across subjects and conditions with no appreciable effect noted.

Effect of vibration on acquisition of erect sitting behavior: Study 4. A multiple baseline design across subjects was used to investigate the effect of vibration on erect sitting behavior with 4 preschool multiply handicapped children. One child with athetosis and 3 children with spastic quadriplegia served as subjects (Table 9). Vibration was applied for 5 seconds each to 12 paravertebral areas on each side of the spine, beginning at the base of the skull an ending at the sacrum for a total of 2 minutes per trial. Measurement of erect sitting was determined by observation of a shoulder marker on a subject positioned sideways to and behind a plexiglass grid divided into six sections (15° each). Recordings were made at 5 second intervals for duration measurements for a total of 3 minutes per trial.

Results over the 7-15 trials of intervention indicated that the duration of erect sitting increased with 2 of the subjects (one with spasticity and one with athetosis), and showed little if any improvement in the other 2 subjects when compared to baseline (Figure 13). Most pre- and post-vibration cumulative duration probes demonstrated near intervention levels of performance, indicating a maintenance effect. The covarying behaviors of postural fixation and protective extension showed little or no improvement.

Table 9

Characteristics of Three Subjects Included in Study 4

Characteristics	Subjects			
	1	2	3	4
Sex	F	M	F	M
Age	4½ years	3 years	3½ years	2½ years
Diagnosis	spastic quadriplegic cerebral palsy, microcephalic	spastic quadriplegic cerebral palsy	athetoid cerebral palsy	spastic quadriplegic cerebral palsy, microcephalic, visually impaired
Postural Tone	increased tone in neck, trunk, and all extremities	increased tone in neck, trunk, and all extremities	fluctuating tone in neck, trunk, and all extremities	increased tone in neck, trunk, and all extremities
History of Seizures	controlled with medication	none	none	controlled with medication
Gross Motor Level	12-14 months	9-10 months	6-8 months	3-6 months
Fine Motor Level	12-14 months	9-10 months	6-8 months	2-3 months
Cognitive Level	16-18 months	9-10 months	9-12 months	2-4 months
Mode of Communication	point; some words	point; some words	eye gaze, head shake	no formal mode
Adaptive Devices	walker	none	none	none

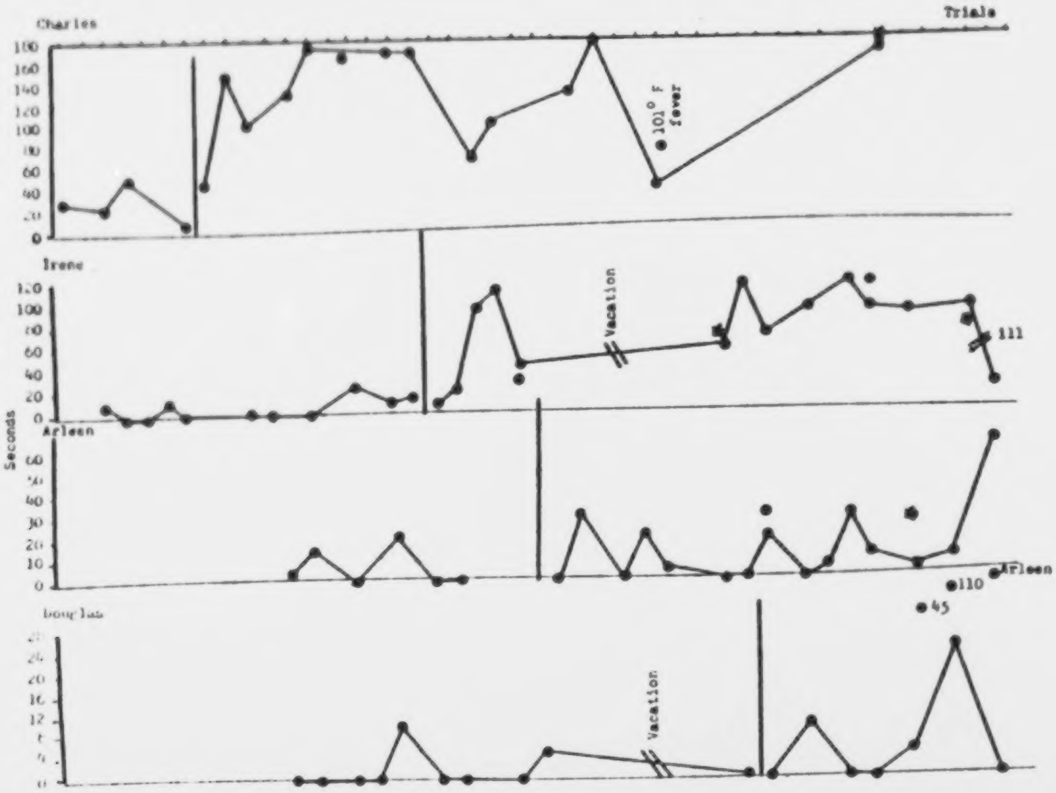

Figure 13. Duration in optimal position recorded in seconds, across subjects

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Effect of vibration on acquisition of sitting behavior: Study 5. A multiple baseline design across subjects was used to assess the effect of vibration on the acquisition of erect sitting behavior in 3 preschool children with severe, multiple handicaps. Two children with spastic quadriparesis and one child with hypotonia served as subjects (Table 10). The cumulative duration of erect sitting was recorded during each 3 minute intervention session. Following baseline observations, vibration was applied to the entire paravertebral area on both sides of the spine for the first 2 minutes of the session. In addition, probes for symmetry of sitting, for the covarying behaviors of protective extension and postural fixation, and for generalization of the target behavior were recorded at least once during the baseline period and three to four times during intervention sessions. Three post-study follow-up sessions were conducted. Results of the study demonstrated an increase in erect sitting behavior in 2 subjects (one with hypotonia and one with spasticity) (Figure 14). There was an increase in the protective extension and postural fixation ability in the subject with hypotonia, and inconclusive results in the remaining behaviors across subjects. No generalization or maintenance of the target behavior were demonstrated.

Effect of vibration on acquisition of sitting behavior: Study 6. The effects of vibration on the acquisition of erect sitting behavior were investigated with 3 preschoolers with multiple handicaps utilizing a multiple baseline design across subjects. One child with spastic quadriparesis, one child with ataxia, and one child with hypotonia participated as subjects (Table 11). Vibration was applied with 2 vibrators simultaneously on the paraspinal muscles from the occiput to the sacrum for 30 seconds. This procedure was repeated four times in a 2-minute time

Table 10

Characteristics of the Three Subjects Included in Study 5

Characteristics	DB	DK	LC
Age	6 years, 2 months	6 years, 6 months	2 years, 4 months
Diagnosis	oral-facial-genial syndrome, aortic stenosis, psychomotor, retardation, seizure disorder	cerebral palsy, mental retardation	occipital encephalocele, microcephaly, developmental delay, vision and hearing impairments, spastic quadriplegia
History of Seizure	seizure at birth controlled with phenobarbital and dilantin	none	seizure at birth, medicated first 4 months only, with phenobarbital
Postural Tone	hypotonic	hypertonic throughout, increased flexor tone in arms	hypotonic trunk and hips, spastic tone of arm and leg flexors
Cognitive Level	0-5 months on Cattel-Binet and Vineland Social Maturity	Ma 1-4 months, IQ 26 on Cattel-Binet; Vineland Score - 11 months	Callier-Azusa Assessment Scale below 6 months in all areas
Speech and Language	receptive language 10 months, expressive language 4 months	Brigance Score 14-24 months	Callier-Azusa Assessment Scale below 6 months
Gross Motor	4-5 months	4-8 months	below 6 months
Fine Motor	gross grasp both hands	good use of right hand; gross grasp with left hand	below 6 months
Communication	differential crying only	2 word sentences	no formal communication

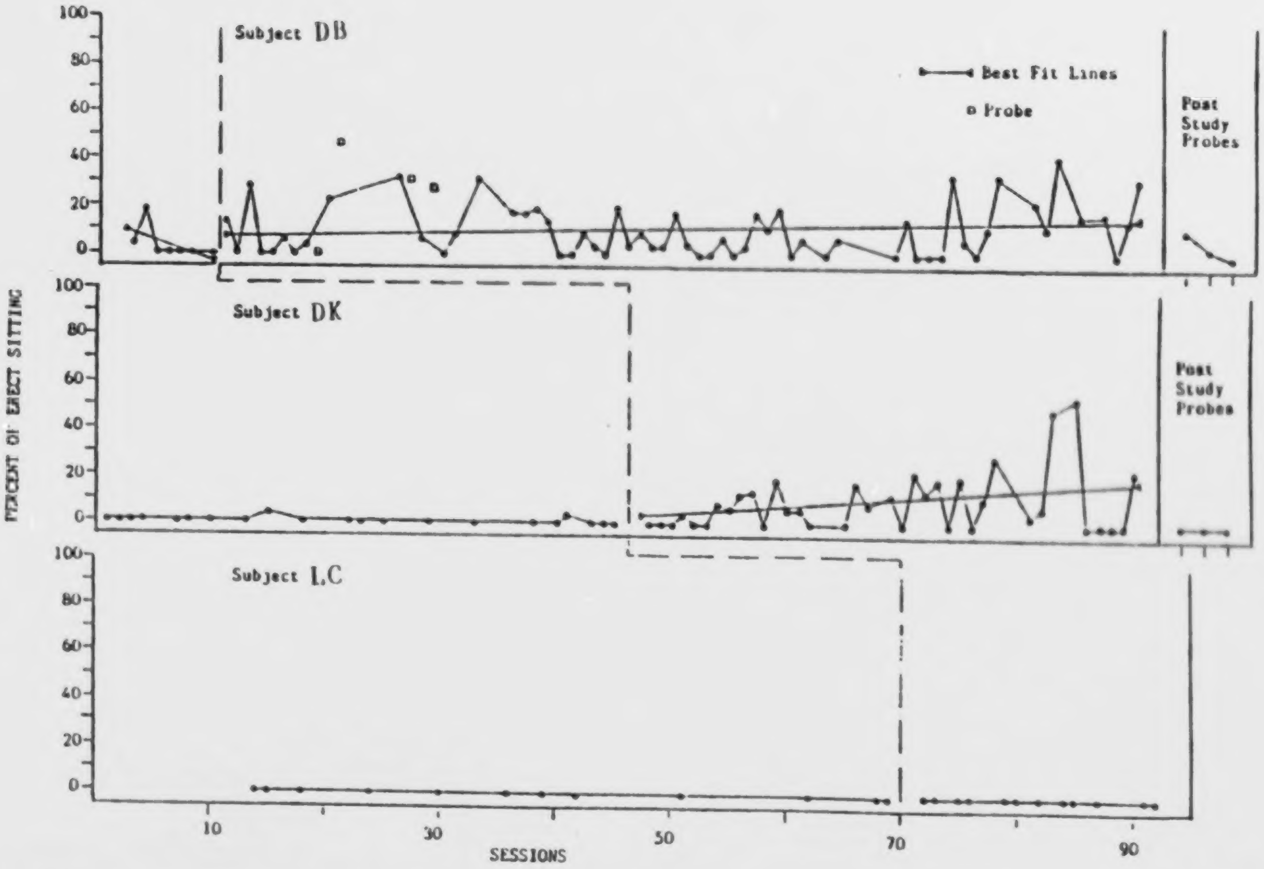

Figure 14. Comparison of erect sitting behaviors in 3 subjects using a multiple baseline design.

Table 11

Characteristics of the Four Subjects Involved in Study 6

Characteristics	TN	MH	BO	JO
Age	5 yrs 2 mos	5 yrs 0 mos	5 yrs 1 mo	6 yrs 0 mos
Diagnosis	Pelizaeus-Merzbacher Disease	Ataxic cerebral palsy	Spastic quadriplegic cerebral palsy, seizure disorder, microcephaly	Spastic quadriplegic cerebral palsy
History of Seizures	None	None	At birth, controlled with medications	With illness, controlled with medications
Gross Motor Level	11 months	10-11 months	2-4 months	2-4 months
Fine Motor Level	2-yrs, 0 mos 2 yrs, 6 mos	12-16 months	0-1 month	2-4 months
Cognitive Level	3 ys, 2 mos	18 months	0-1 month	4-5 months
Language	32-33 months receptive 32-33 months expressive	30 months receptive 19 months expressive	0-1 month	6 months receptive 6 months expressive
Adaptive Devices	None	None	Polyurethene ankle-foot orthoses	Gastrointestinal tube, tracheostomy tube

period. Measurement of erect sitting was conducted during vibration and for one minute following the cessation of vibration. Probe measures on potential covarying behaviors of shoulder symmetry, protective extension, and postural fixation were also obtained. Results indicated that the child with ataxic cerebral palsy improved in her ability to maintain erect sitting as well as improved in the postural fixation response. Post study follow-up probes indicated continued maintenance of the targeted behavior (Figure 15). The other 2 children did not demonstrate significant change in the target behavior or potential covarying behaviors.

Integrated Summary

In the 6 studies completed utilizing vibration as the independent variable, our data suggest that this technique may have a basic effect on both head erect and sitting behaviors in some young children with severe and multiple handicaps. The 3 subjects involved in the head erect study and 5 of the 10 subjects in the sitting studies demonstrated an increase in the dependent variable with the application of vibration. The results of the study on upper extremity weight bearing were less clear as the topography of the target behavior varied across subjects; for this reason the subjects in this study are omitted from the following discussion.

Subject characteristics were analyzed across the above studies to determine if a differential effect for age or type of motoric impairment emerged. The ages of the 8 youngsters who demonstrated an increase in the dependent variable (i.e., head erect or sitting) ranged from 1½ to 6½ years. The type of motoric impairment included: spasticity (3), hypotonia (2), athetosis (2); and ataxia (1). Three of the 8 children were currently on medication for seizure control. For the 5 youngsters

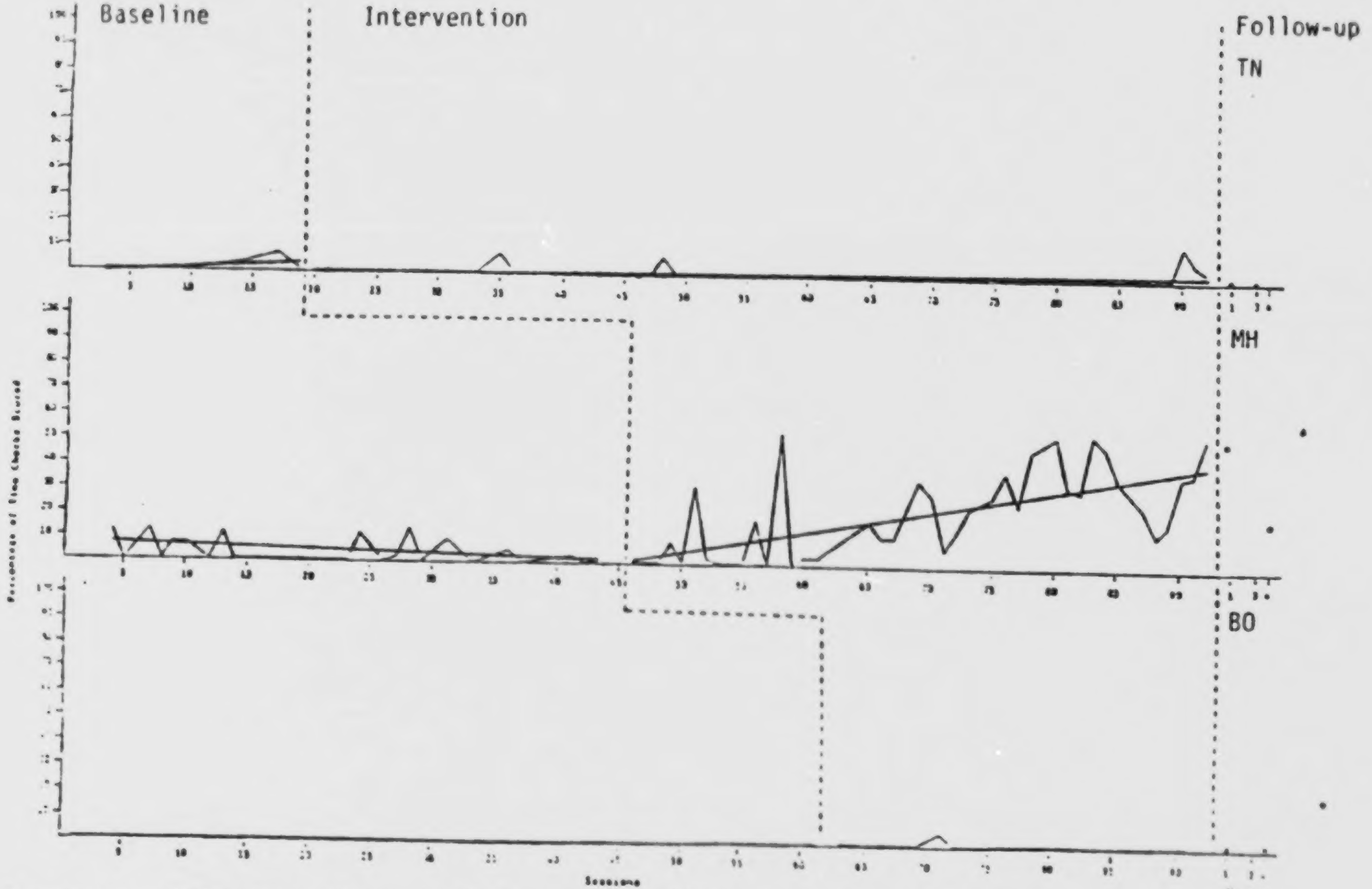

Figure 15. Percentage of erect sitting across all subjects and all conditions.

who showed no discernible improvement, ages ranged from 2½ years to 5 years; 4 children presented with spasticity and one with hypotonia. Four of these 5 children were currently on medication for seizure control.

Although generalizations are difficult due to the small population, several possible trends are noted: (1) age did not appear to be a variable; (2) the outcomes for children with extrapyramedal symptoms (e.g., athetosis, hypotonia, ataxia) were generally favorable with 5 out of the 6 children demonstrating increases in the dependent variable; (3) the outcomes for children with pyramidal symptoms (e.g., spasticity) were less consistent with 4 of the 7 subjects demonstrating no discernible response; and (4) seizure disorders occurred more frequently in subjects with spasticity (6 of 7) than in subjects with other movement disorders (1 of 6). Four of the above subjects with spasticity who showed no change in the dependent variable during the intervention condition also presented with seizure disorder.

Generalization and maintenance. The initial vibration study on head erect behavior primarily investigated the basic effects of the technique with little emphasis placed on generalization and maintenance. The 3 studies investigating the effects of vibration on sitting more systematically addressed these issues.

In Study 4, pre- and post-intervention probes were scheduled from 25-50 minutes before or after an intervention session. Data from these probes generally resulted in duration scores for erect sitting equivalent to intervention trials. This finding suggested maintenance of treatment effects across trials. Longitudinal follow-up data were not collected in this study.

In Studies 5 and 6 generalization probes were conducted at least once during baseline and every fifth to tenth session during intervention. No appreciable generalization of the dependent variable occurred in non-experimental settings during these probe sessions. Maintenance of treatment effects following termination of the intervention occurred for only one subject. The absence of generalization and maintenance of treatment effects on follow-up may be related to degree of acquisition of the target behavior. Although 3 of the 6 subjects in these 2 studies demonstrated improvements in the dependent variable; the level of responding only exceeded 50% of the time checks for one subject. Interestingly this was the subject who demonstrated maintenance during follow-up sessions.

For the majority of subjects who evidenced change in the dependent variable, the increases did not approximate acquisition levels of performance. In addition, successive data points during intervention were often marked by fluctuations rather than a smooth acceleration trend. For children with severe, multiple handicaps, this uneven response to therapeutic techniques may characterize their acquisition pattern. Although gains were small, for some individual subjects these gains may be viewed as significant. Given the short duration of these basic effects studies, the results strongly suggest the need for additional longitudinal research. Longitudinal research would allow for a clearer analysis of acquisition patterns, provide data on the level of acquisition necessary for maintenance and generalization, and contribute to our data base on the differential effects across handicapping conditions.

Potential adverse reactions. A total of 21 subjects were involved in the 6 vibration studies. Two subjects were discontinued from their respective studies, one due to repeated hospitalizations and fragile health, the second due to a perceived adverse reaction to the vibration. As vibration was applied to the paraspinal back extensors, this youngster extended backward out of the sitting position. He did not indicate discomfort through either facial expressions or vocal behavior (e.g., crying, whining) but rather over-responded motorically to the stimulus. This hyperextension did not diminish over the first few intervention sessions and in order not to reinforce this nonfunctional behavior, we discontinued him from the study.

Of the 19 subjects remaining in the studies, 11 were currently on medication for seizure control. For 9 of the 11 there was 100% agreement across conditions on the nonoccurrence of seizures. Seizures did occur in 2 subjects but the frequency was similar to that recorded during the baseline condition. These youngsters were monitored carefully and with parental and physician consent continued in the study.

Covariation probes. Data on potential covarying behaviors were collected across conditions in each of the 6 studies. These data consistently demonstrated no or only miniml change in behaviors which were functionally and developmentally related to the respective dependent variables (i.e., head erect and sitting).

In a normal development model, the dependent variables are prerequisite for the development of the covarying behaviors selected for these studies. For example, a child generally maintains the head in the erect position before propping on forearms or extended arms emerges. Similarly, stability in sitting precedes the development of postural fixation and protective extension responses. Although gains in the dependent variables were noted for some subjects, no subject demonstrated complete acquisition of either head erect or sitting behavior. This lack of acquisition may partially explain the overall negative results for the covariation probes. That is, the developmental prerequisite for the skills was itself still in the developmental process. This is an additional area which will best be addressed through a program of longitudinal research.

Vestibular Stimulation

Five studies were completed investigating the effects of rotary vestibular stimulation on basic motor behaviors. The dependent variables were: head erect - 3 studies; and sitting - 2 studies. Interobserver agreement for the dependent variables was acceptable in each of the five studies. The methodology employed was drawn from the existing literature and incorporated a rapid acceleration, 1 minute of constant velocity, an impulsive stop and an intertreatment interval. Because the subjects in these studies wre unable to provide their own stimulation or verbally request more or less timulation, the methodology reflected a conservative approach in relation to the total duration of vestibular stimulation per session. For each successive study, the total duration of vestibular stimulation was gradually increased until in the final studies a methodology was employed allowing for an increase in duration within the study.

Effects of vestibular stimulation on head erect in prone: Study 7.

This study utilized a multiple baseline design to ivnestigate the effects of 4 minutes of vestibular stimulation (Method A) on head erect behavior in three preschoolers with severe and multiple handicaps. One child with athetosis, one child with spasticity and one child with hypotonicity served as subjects (Table 12). Measurement procedures consisted of recording the frequency and cumulative duration of head erect in the prone position. Following baseline observations, each child was manually

Table 12

Characteristics of the Three Subjects in Study 7

CHARACTERISTICS	SUBJECTS		
	1	2	3
Sex	F	F	M
Age	5 years	3 years	5 years
Diagnosis	athetoid cerebral palsy	acardia syndrome	spastic quadriplegic cerebral palsy hydrocephalic
Postural Tone	fluctuating tone in all extremities	hypotonic in neck, trunk, and extremities	increased tone in neck, trunk, and extremities
History of Seizures	none	controlled with medication	controlled with medication
Gross Motor Level	4-6 months	2-3 months	4-6 months
Fine Motor Level	6-9 months	2-3 months	4-6 months
Cognitive Level	3-9 months	5-6 months	4-6 months
Mode of Communication	eye gaze	no formal mode	no formal mode
Adaptive Devices	none	none	none

spun in a vestibular box for 4 minutes in two positions (sitting and sidelying). Probes were conducted on two covarying behaviors; upper extremity weight bearing and visual fixation, as well as short term maintenance of the target behavior. The results indicated a minimal effect for 2 subjects with slight increases in the cumulative duration of head erect (see Figure 16). Probes conducted for potential covarying behaviors did not demonstrate change.

Effects of vestibular stimulation on head erect in prone: Study 8. This study used a multiple baseline design across subjects to investigate the effects of 6 minutes of vestibular stimulation (Method B) on head erect behavior in preschoolers with multiple handicapped. Three children with spasticity and one with hypotonicity served as subjects (Table 13). Frequency of head lifts and cumulative duration of head erect were recorded in a 3 minute time sample. Following baseline observations each child was manually spun in a vestibular box in three different positions (sitting, right and left sidelying). Probes for potential covarying behaviors of visual fixation and upper extremity weight bearing were conducted across conditions. Results indicated a mean increase in cumulative duration for the 3 subjects presenting with spasticity; for 2 of the 3 subjects these increases were small (Figure 17). No changes were noted in the covarying behaviors.

Effect of vestibular stimulation on head erect in prone: Study 9. A multiple baseline design across subjects was used to assess the effect of vestibular stimulation on the acquisition of head erect behavior in preschool children with multiple handicapping conditions. Three children with spasticity and one with hypotonia served as subjects (Table 14). The cumulative duration of head erect behavior was recorded for 3 minutes

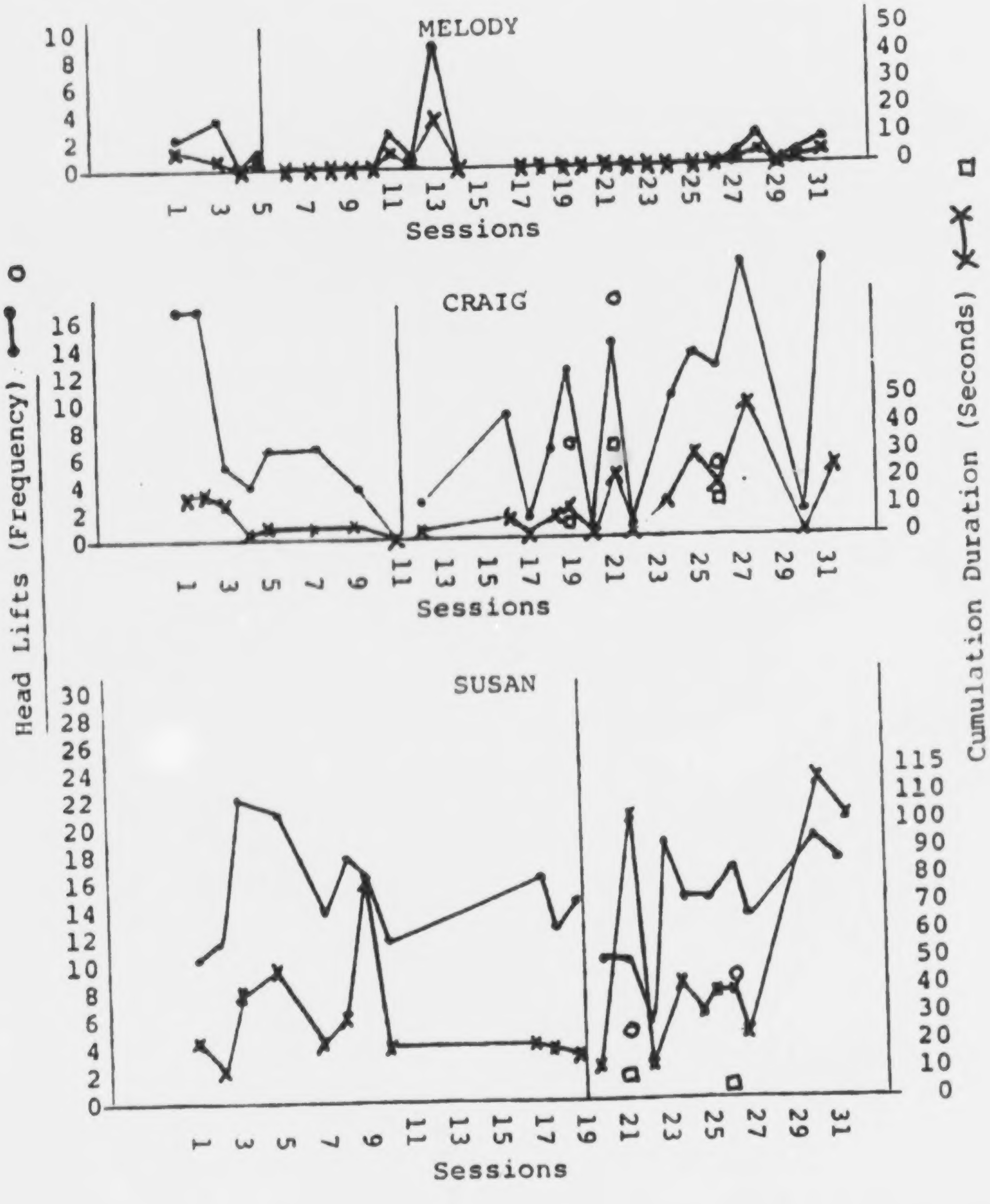

Figure 16. Frequency of head lifts and cumulative duration of head erect behavior across subjects.

Table 13

Characteristics of the Four Subjects Included in Study 8

Characteristics	Subjects			
	1	2	3	4
Age	1.6 years	3 years	2.5 years	3.6 years
Diagnosis	spastic quadriplegia cerebral palsy, microcephalic	spastic quadriplegia cerebral palsy	spastic quadriplegia, microcephalic	hypotonic qudriplegia, acardia syndrome
History of Seizures	Infantile spasm, on phenobarbital, and depakene	none since birth	none	myoclonic infantile spasms, on phenobarbital and clonapin
Gross Motor Abilities	no mobility	roll prone to supine, prop sit for short period	no mobility	rolls indep. both direct.
Fine Motor Abilities	no functional reach or grasp	bat at objs.	no functional reach or grasp	transfer obj. voluntary reach and grasp
Cognitive Level*	1 month	8 months	1-2 months	5-6 months
Modes of Communication	no formal mode	eye gaze	no formal mode	no formal mode

* Bayley Scale of Infant Development

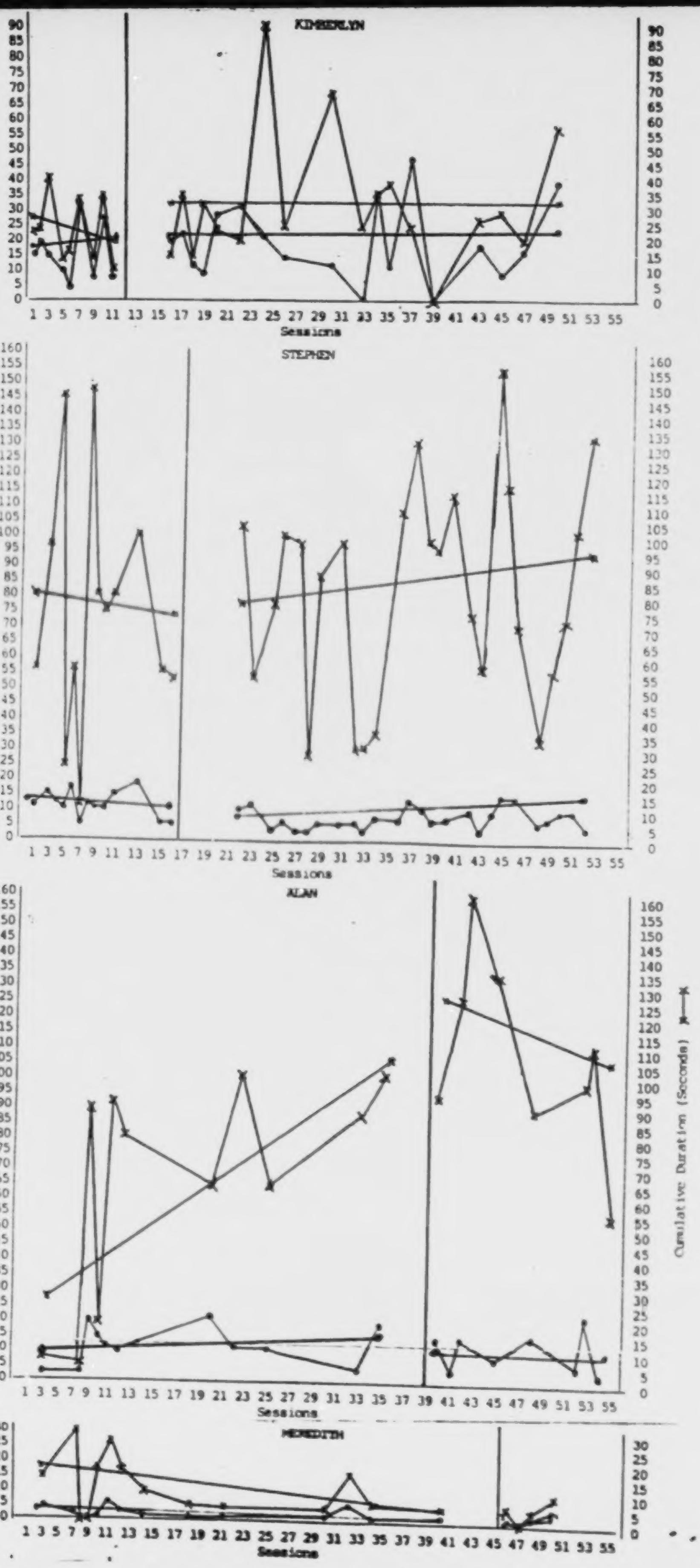

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Figure 17. Frequency of head lifts and cumulative duration of head erect behavior across subjects.

Table 14

Characteristics of the Four Subjects Included in Study 9

Characteristics	Subjects			
	O.D.	K.M.	A.M.	D.R.
Age	2 yrs 6 mos	1 yr 6 mos	4 yrs	2 yrs 6 mos
Diagnosis	spastic cerebral palsy, visual problems	hypotonic cerebral palsy, microcephaly	spastic cerebral palsy	spastic quadriplegic cerebral palsy
Postural Tone	increased tone all extremities, decreased tone in trunk	decreased tone in extremities and trunk	increased tone in extremities, decreased tone in trunk	increased tone in extremities, decreased tone in trunk
History of Seizures	none	at birth, controlled with phenobarbital	none	at birth, controlled with phenobarbital
Gross Motor Level	5-6 mos	2-3 mos	5-6 mos	3-4 mos
Fine Motor Level	5-6 mos	2-3 mos	5-6 mos	3-4 mos
Cognitive Level	9-10 mos	1-2 mos	9-10 mos	5-6 mos
Modes of Communication	no formal mode	no formal mode	eye gaze	no formal mode

following baseline and intervention sessions. Following baseline observations, each subject was manually spun in a platform swing for a cumulative duration of 8 or 10 minutes (Method C) in four different positions (upright sitting, supine, right and left sidelying). In addition, probes for vocalizations, for the covarying behaviors of upper extremity weight-bearing, post-rotary nystagmus, and for generalization of the target behavior were conducted at least once during baseline and every fifth session during intervention. Results of the study indicated an increase in the target behavior for the 3 subjects with spasticity; the increase was minimal for one of these subjects (see Figure 18). One subject's data were confounded by hip surgery. These subjects also demonstrated generalization of the target behavior and a maintenance effect in the follow-up sessions (Figure 19). An increase in upper extremity weight bearing was evidenced in 1 of the 3 subjects.

Effects of vestibular stimulation on sitting behavior: Study 10. A multiple baseline design across subjects was used to assess the effects of vestibular stimulation (Method D) on the acquisition of erect and symmetrical sitting in preschoolers with severe and multiple handicaps. Three children, two with athesosis and one with spasticity served as subjects (Table 15). Measurements of erect and symmetrical sitting were taken in separate 3 minute time samples. Following baseline observations, each child was manually spun in a platform swing for 6 or 8 minutes in three different positions (sitting, right and left sidelying). Probes for potential covarying behaviors of protective extension and postural fixation were conducted across conditions. All 3 subjects made gains in erect sitting (Figure 20). Results from the symmetrical sitting measure were less conclusive (Figure 21). No changes were noted in the

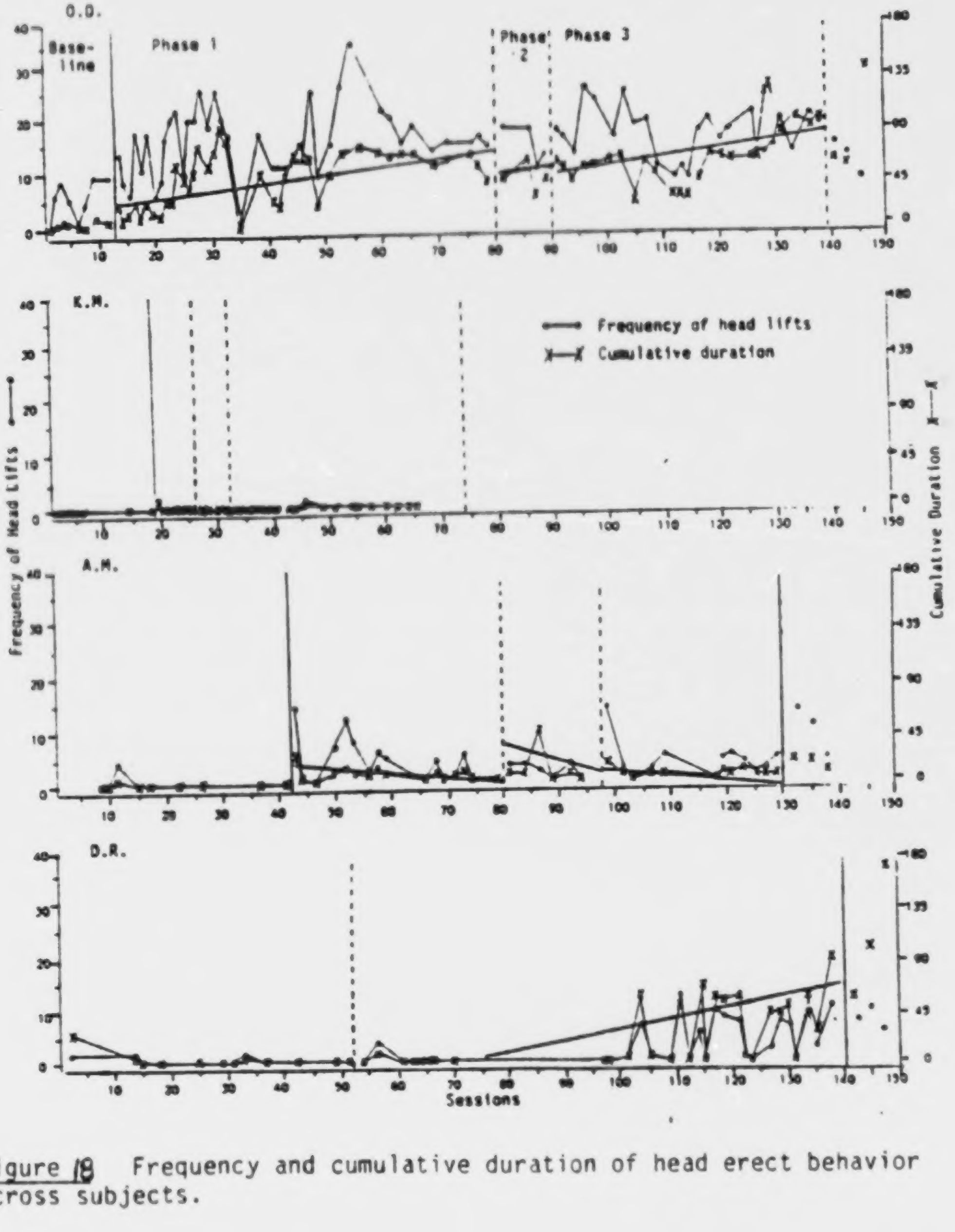

Figure 18 Frequency and cumulative duration of head erect behavior across subjects.

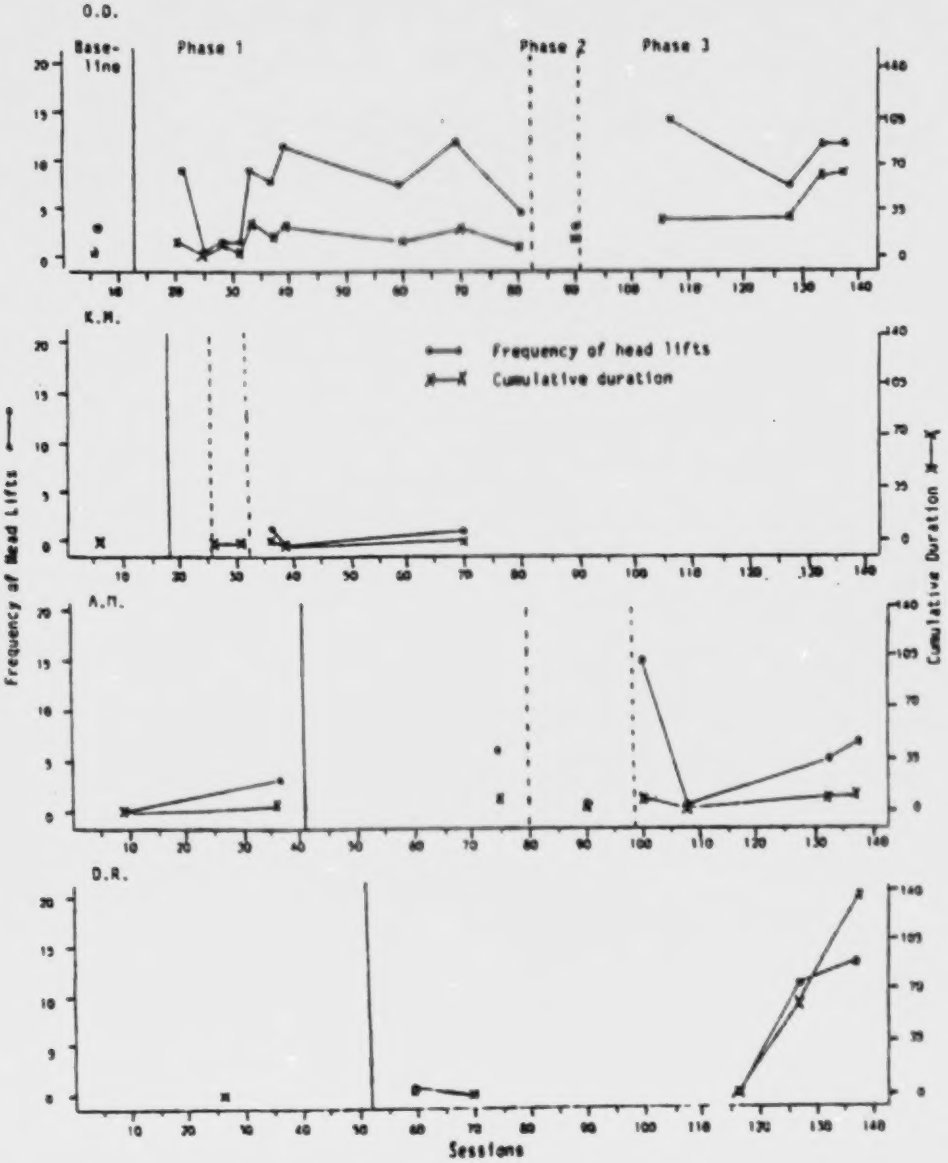

Figure 19. Generalization performance data across subjects and conditions.

Table 15

Characteristics of the Three Subjects Included in Study 10

Characteristics	Subjects		
	Stephen	Jennifer	Thomas
Age	4 years 10 months	3 years 0 months	3 years 4 months
Diagnosis	Athetoid cerebral palsy, moderate severe bilateral sensorineural hearing loss	Spastic quadriplegic cerebral palsy, severe bilateral sensineural hearing loss	Athetoid cerebral palsy, severe-profound bilateral sensineural hearing loss
Postural Tone	Fluctuating tone in all extremities including neck and trunk	Increased tone in extremities with extensor tone in neck and trunk	Fluctuating tone in all extremities including neck and trunk
History of Seizures	None	at birth, controlled with phenobarbital	None
Gross Motor Level	10-11 months	6-7 months	17-18 months
Fine Motor Level	18-30 months	4-5 months	25-26 months
Cognitive Level	23-24 months	1-2 months	18-19 months
Modes of Communication	no formal code	eye gaze	sign language communication board and book
Adaptive Devices	Bilateral hearing aids, Polyurethane ankle-foot orthoses	Bilateral hearing aids, corrective glasses	Unilateral hearing aid

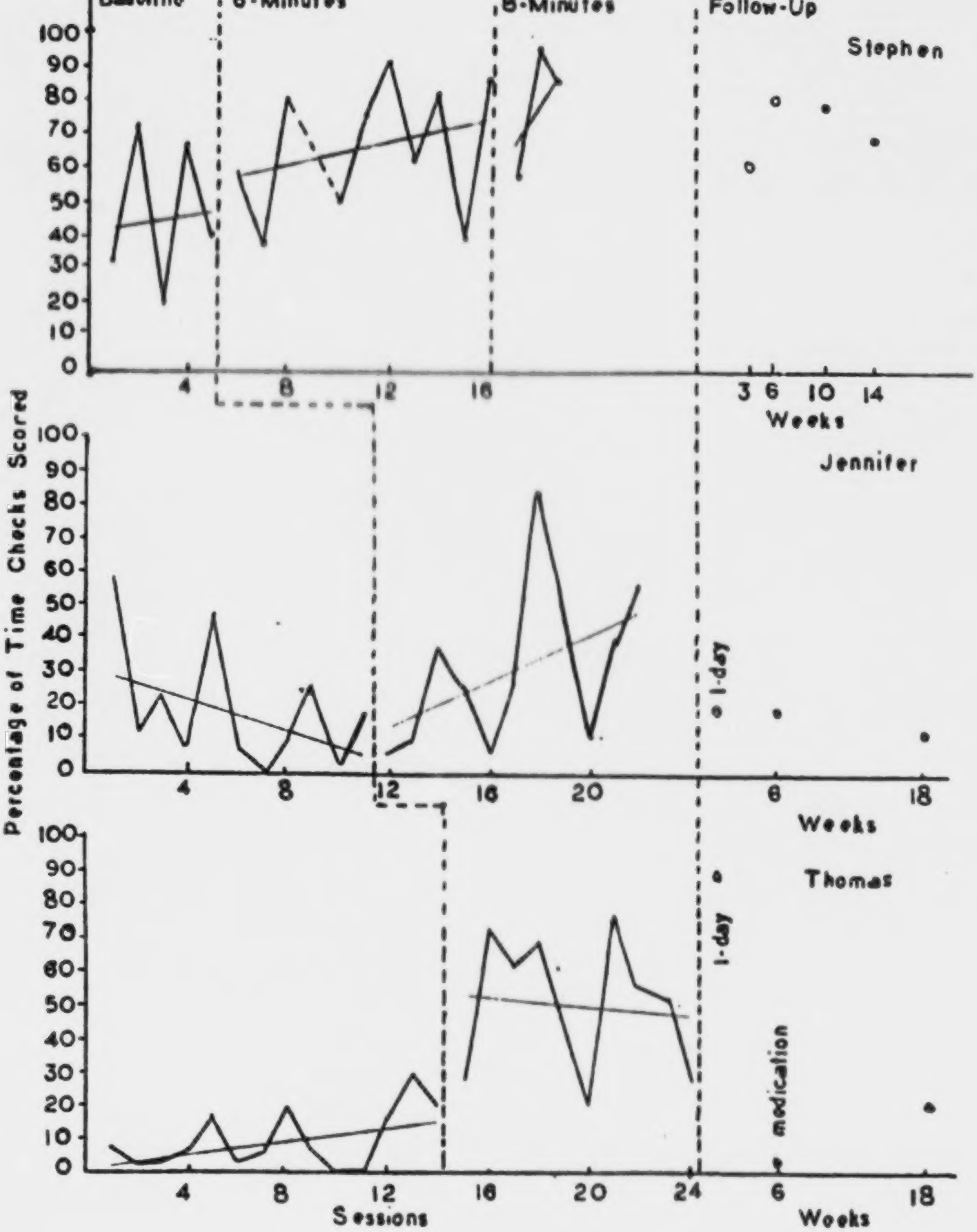

Figure 20. Percentage of erect sitting across all subjects and conditions.

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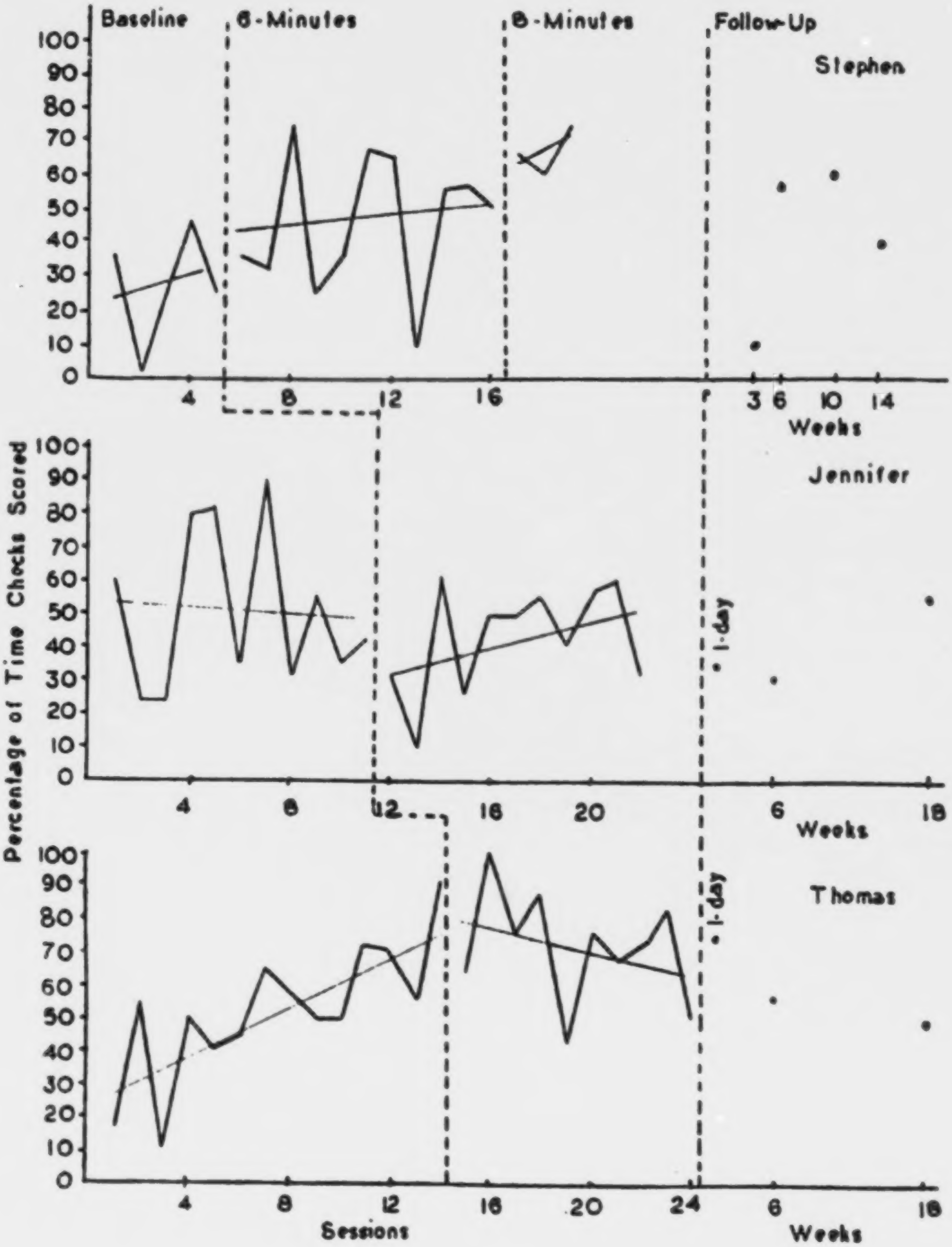

Figure 21. Percentage of symmetrical sitting across all subjects and conditions.

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covarying behaviors. The 2 subjects with athetosis appeared to maintain these gains across a 4-month follow-up period while the subject with hypertonicity did not.

Effects of vestibular stimulation on sitting: Study 11. A multiple baseline design across subjects was used to assess the effects of vestibular stimulation on the acquisition of erect sitting behavior in preschool children with multiple handicapping conditions. Three children with spasticity and one child with fluctuating muscle-tone served as subjects (Table 16). Measurements of erect sitting were taken in 3 minute time samples following vestibular stimulation. Following baseline observations, each subject was manually pun in a platform swing for a cumulative duration of 6 or 8 minutes (Method D) in three different positions (upright sitting, right, and left sidelying). In addition, probes for arm support/free arm sitting, postrotary nystagmus, protective extension, and postural fixation were conducted across conditions. Results of the study indicated an increase in erect sitting in three of the four subjects with the implementation of vestibular stimulation (Figure 22). For the three subjects who improved with intervention, generalization probes during the study and 6 weeks following the study indicated that it took time before erect sitting generalized to other settings. There were no changes in the covarying behaviors.

Integrated Summary

In the 5 studies completed utilizing vestibular stimulation as the independent variable, we investigated the effects of several different methods or durations of this therapeutic technique. We systematically increased the duration of stimulation in successive studies based on

Table 16

Characteristics of the Four Subjects Included in Study 11

Characteristics	Subjects			
	T.M.	C.Y.	J.F.	M.J.
Age	3 yrs 5 mos	4 yrs 1 mo	3 yrs 0 mo	5 yrs 1 mo
Diagnosis	multiple congenital anomalities	spastic quadriplegic cerebral palsy	spastic quadriplegic cerebral palsy	spastic quadriplegic cerebral palsy
Postural Tone	fluctuating tone in extremities; decreased tone in trunk	increased tone in lower extremities; decreased in trunk	increased tone in all extremities; decreased in trunk	increased tone in all extremiities; decreased in trunk
History of Seizures	5 grant mal seizures; no current medications	none	at birth; no current medication	2 grant mal seizures; 60 mg phenobarbital daily
Gross Motor	6 mos	12 mos	2 mos	7 mos
Fine Motor	9 mos	3 yrs	12 mos	2 yrs
Social/ Behavioral	18 mos	3½ yrs	12 mos	3½ yrs
Receptive Language	18 mos	4 1/3 yrs	19 mos	28 mos
Expressive Language	18 mos	3 1/3 yrs	19 mos	30 mos

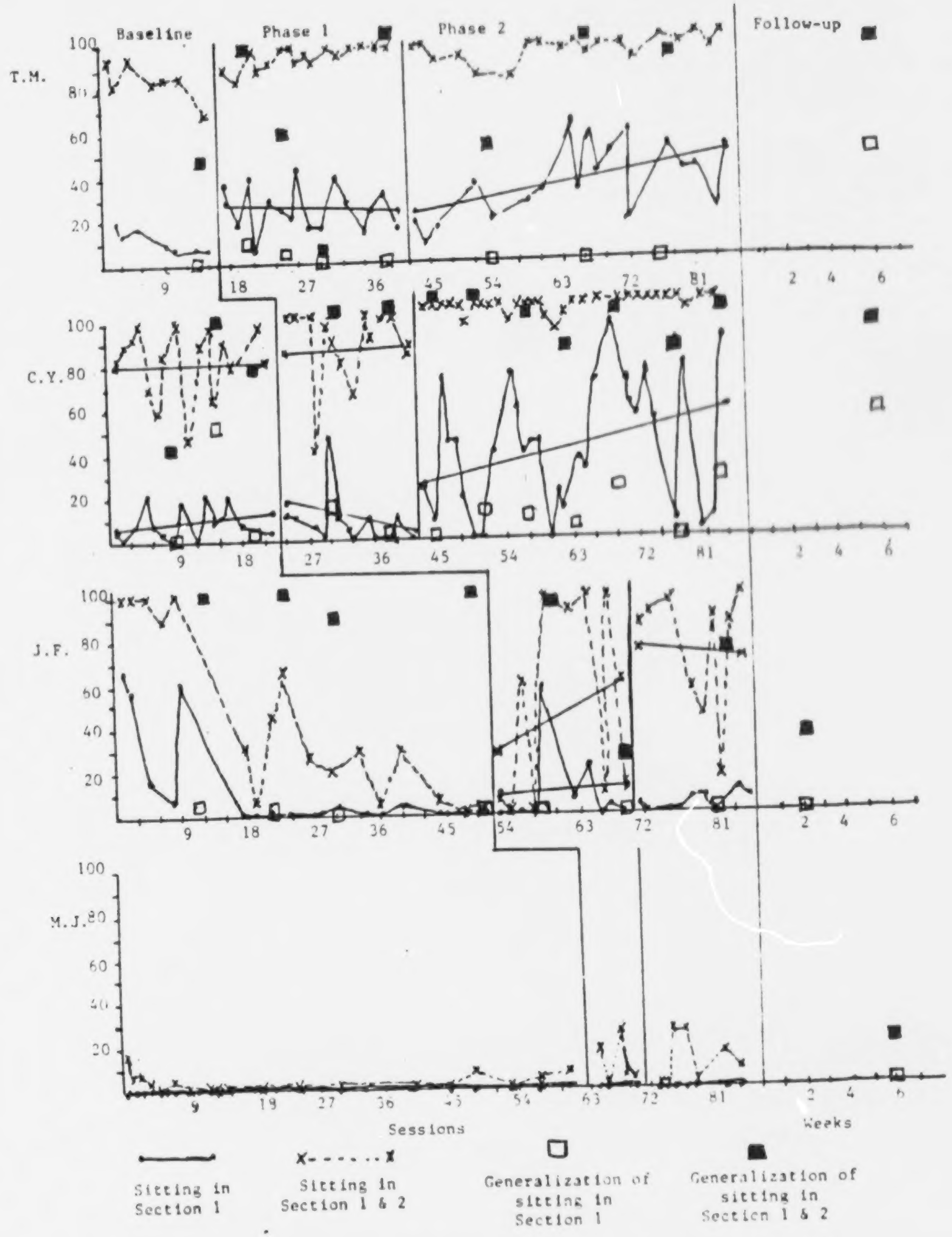

Figure 22. Percentage of erect sitting across all subjects and conditions.

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both performance measures and affective responses (including seizures) of subjects.

Our early head erect studies utilizing 4 and 6 minutes of stimulation yielded only equivocal results. In the final head erect study and for the 2 sitting studies (Study 9-11), we implemented a methodology that allowed for an increase in duration of the stimulation within the study. This modification provided a degree of flexibility that may be important for future research on the effects of this technique. It may be erroneous to assume that the intensity of stimulation necessary to facilitate the vestibular system is the same for all children with severe and multiple handicaps. Our data indicate that children differentially responded to the various durations of stimulation.

The results across studies indicate that this therapeutic technique may have a basic effect on head erect and sitting for some children with severe and multiple handicaps. A mean increase in the dependent variable occurred for 8 of the 10 subjects in the head erect studies and for 6 of 7 subjects in the sitting studies. The increases were small for some youngsters, particularly those in the first 2 (Study 7-8) head erect studies.

Subject characteristics were analyzed across the above studies to determine if a differential effect for age or type of motoric impairment emerged. The ages of the 13 youngsters who demonstrated an increase in the dependent variable ranged from 1 to 5 years. The type of motoric impairment included: spasticity (9); athetosis (3); and hypotonia (2). Six of the 13 were currently on medication for seizure control. For the 3 youngsters who showed no discernible improvement, ages ranged from 2 to 5 years; one child presented with spasticity and 2 with hypotonia.

Two of the 3 children were currently on medication for seizure control. An analysis of the basic effects issue suggest that children with a wide range of motoric impairment benefited from vestibular stimulation. The results of this group of studies suggested a more generalized effect than occurred in the vibration studies. In addition, data collected on affective responses indicated that the majority of children appeared to enjoy the stimulation as evidenced by vocalizations, smiles, and generally more alert behavior.

Postrotary nystagmus. Measurements of postrotary nystagmus as outlined by Ayres (1976) were also conducted during the final 3 studies (Study 9-11) in an effort to assess the functional state of the vestibular system. Normative data on postrotary nystagmus (PRN) suggest that this measurement may be used to indicate responsiveness to vestibular stimulation (Punwar, 1982). We encountered difficulties in both collecting and interpreting these data. For the 11 subjects involved in these 3 studies, 2 had resting nystagmus which precluded their involvement in data collection and one was younger than the available norms. Both youngsters with resting nystagmus evidenced an effect from the stimulation. Of the 8 remaining subjects, 7 demonstrated some change in the dependent variables (i.e., head erect or sitting) and 6 of these maintained above baseline levels of performance on post-study follow-up probes. For these 6 youngsters, 3 demonstrated a decrease in PRN during intervention which placed them in the hyporeactive range according to the data of Punwar (1982). Ayres (1978) findings suggest that subjects with hyporeactive PRN are more responsive to vestibular stimulation therapy than are those with hyperreactive PRN. But for the remaining 3 youngsters there were no changes between baseline and intervention probes for PRN. It is clear that this is an area for additional study to determine the relative value of assessing PRN as a potential indicator of the subject's responsiveness to the stimulation.

Generalization and maintenance. Generalization probes conducted across 3 studies (Study 7, 9, 11) demonstrated a gradual increase in the dependent variable in non-contrived settings for some subjects. This trend was apparent for 3 of the 8 subjects who showed acquisition levels of 50% or more for the dependent variable (i.e., head erect or sitting). These data did not approximate intervention levels of acquisition that were generally more stable than the performance data. The performance data, like that of the vibration studies, was characterized by fluctuations in successive data points.

Follow-up probes were conducted in the final 3 studies (Study 9-11) to assess maintenance of therapeutic change over time. These data were collected from 1 to 18 weeks following the completion of the individual studies. A maintenance effect approximating intervention levels of performance was observed in 8 of the 10 subjects. These data are extremely encouraging in that document of long term maintenance increases the functionality of the therapeutic technique. A program of longitudinal research to further assess generalization and maintenance and their respective relationships to acquisition levels is recommended in view of the above findings.

Potential adverse reactions. A total of 16 subjects were involved in the 5 vestibular stimulation studies. Eight of the 16 were currently on mediation for seizure control. For 4 of the youngsters there was 100% agreement across conditions on the nonoccurrence of seizures. The seizure pattern varied among the other 4 children with a decrease in the mean of frequency from baseline to intervention for one subject and a slight increase for the remaining 3 subjects. These youngsters were monitored carefully and with parental and physician consent continued in the study. Two of the 3 youngsters who evidenced an increase in seizures demonstrated no discernible effect from the intervention.

An additional issue in monitoring seizures involves parental compliance with medication regimes. For one of the youngsters who demonstrated an increase in seizures during the intervention condition, his mother reported that she had forgotten to give the medication on 2 of the 3 days that the youngster had seizures.

Covariation probes. Probes for potential covarying behaviors were conducted across the 5 vestibular stimulation studies. With only one exception, these data demonstrated no or only minimal change in behaviors which were functionally and developmentally related to the dependent variables (i.e., head erect and sitting). Although subjects in the vestibular stimulation studies generally demonstrated a higher level of acquisition than those in the vibration studies, the performance level was not sufficient for the emergence of covarying behaviors. Again this is an area which will best be addressed through a program of longitudinal research.

Inversion

Two studies were completed investigating the effects of inversion on head erect behavors. There were no published studies on the inversion procedure to assist us in defining the parameters of this intervention. The following studies investigated the effects of a dynamic and static form of inversion. The duration of inversion resulted from piloting the procedure across subjects to determine tolerance and endurance for the position. Interobserver agreement for the dependent variable was acceptable across studies.

Effects of inversion on head erect in prone: Study 12. A multiple baseline design was used to investigate the effects of a dynamic method of inversion (Method A) on head erect behavior in preschoolers with multiple handicaps. Four children, 2 with spasticity and 2 with spasticity and athetosis, served as subjects (Table 17). Measurement procedures consisted of recording the frequency of head lifts and cumulative duration of head erect in the prone and inverted positions. Following baseline observations, each child was manually inverted over a barrel. Probes for potential covarying behaviors (i.e., upper extremity weight bearing and visual fixation) were conducted across conditions for all subjects. Blood pressure was also measured periodically to monitor adverse reactions to the intervention procedure. Positive effects of inversion were observed in 2 of the 4 subjects; the first subject showing an increase in cumulative duration of head erect behavior in the post intervention measurement period (Figure 23) and one subject exhibiting an increase in cumulative duration of head erect during the intervention (Figure 24). There were no changes in the covarying behaviors.

Effect of inversion on head erect behavior in prone: Study 13. A multiple baseline design across paired subjects was used to investigate the effects of a static method of inversion (Method B) on head erect behavior of preschool children with multiple handicaps. Four children with spasticity served as subjects (Table 18). Measurement procedures consisted of recording the cumulative duration of head erect and the frequency of head lifts in the prone inverted position. An additional probe was conducted to measure head erect on the prone horizontal surface

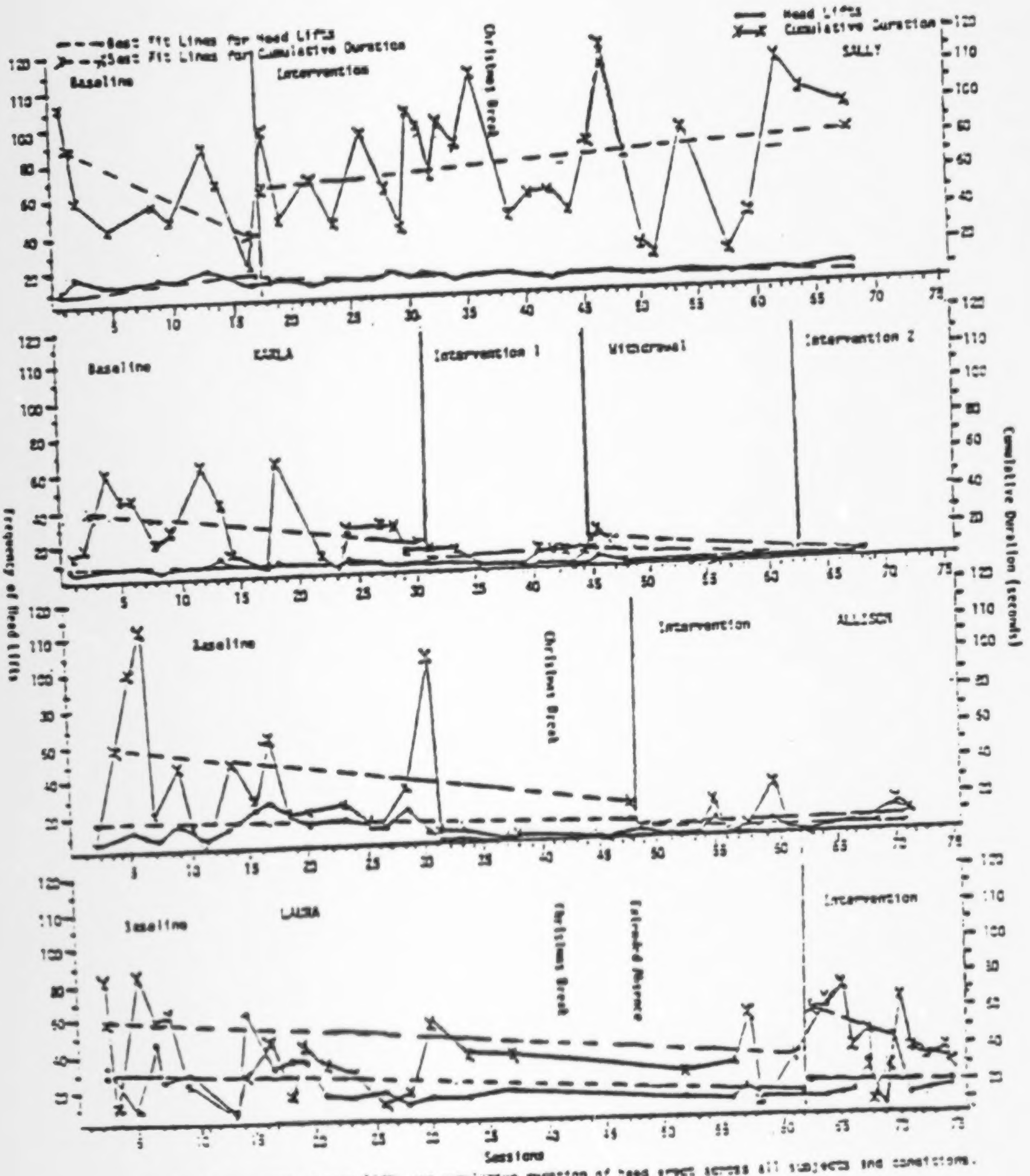

Figure 23 Frequency of head lifts and cumulative duration of head erect across all subjects and conditions.

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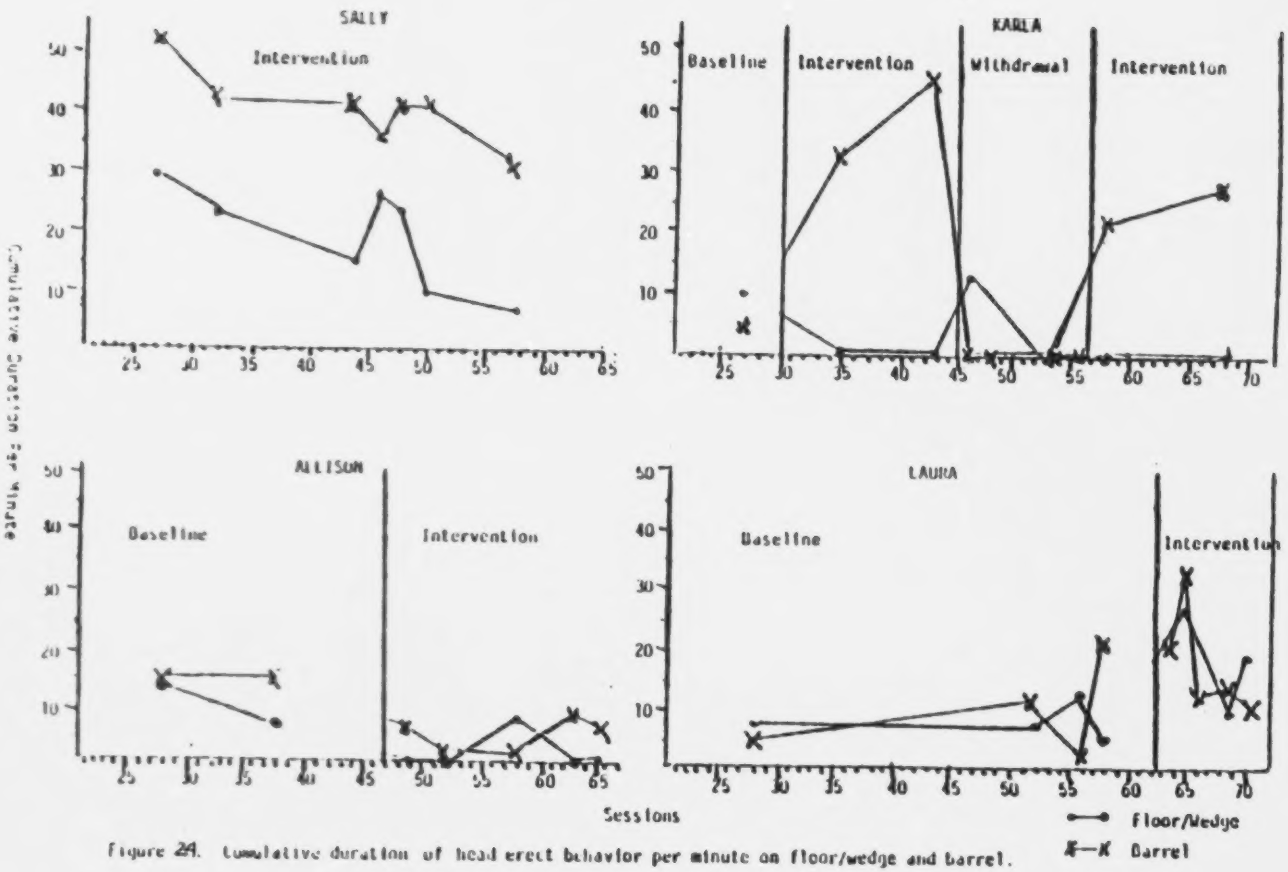

Figure 24. Cumulative duration of head erect behavior per minute on floor/wedge and barrel.

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Table 17

Characteristics of Four Subjects Included in Study 12

Characteristics	Subjects			
	1	2	3	4
Sex	F	F	F	F
Age	3½ years	1½ years	3½ years	3½ years
Diagnosis	spastic quadriplegic cerebral palsy, moderate bilateral sensorineural hearing loss	mixed type cerebral palsy	spastic quadriplegic cerebral	spastic quadriplegic cerebral palsy
Postural Tone	increased tone in extremities, neck and trunk	increased tone in extremities, decreased in neck and trunk	increased tone in all extremities neck and trunk	increased tone in all extremities, decreased in neck and trunk
History of Seizures	at birth, nonce since	none	at birth, none since	none
Gross Motor Level	6-7 months	8 months	4 months	1-2 months
Fine Motor Level	4-5 months	4 months	3 months	1-2 months
Cognitive Level	5-6 months	8 months	5 months	1-2 months
Mode of Communication	eye gaze	eye gaze, point	eye gaze	no formal mode
Adaptive Devices	bilateral hearing aids, corrective glasses	corrective glasses	none	polyurenthane hand splints

Table 18

Characteristics of the Four Subjects Included in Study 13

Characteristics	Subjects			
	Jennifer	Taylor	Alice	Amy
Age	3 yrs 7 mos	1 yr 3 mos	3 yrs 6 mos	3 yrs, 3 mos
Diagnosis	spastic quadriplegic cerebral palsy, moderate bilateral sensineural hearing loss	mixed type cerebral palsy	spastic quadriplegic cerebral palsy	spastic quadriplegic cerebral palsy, microcephalic
Postural Tone	hypertonicity in all extremities, neck and trunk	hypertonicity in all extremities, hypotonicity in neck and trunk	hypertonicity in all extremities, neck and trunk	hypertonicity in all extremities, hypotonicity in neck and trunk
History of Seizures	seized at birth, none since	none	seized at birth, none since	none
Gross Motor Level	6-7 months	8 months	4 months	1-2 months
Fine Motor Level	4-5 months	4 months	3 months	1-2 months
Cognitive Level	5-6 months	8 months	5 months	1-2 months
Model of Communication	eye gaze	eye gaze; point	eye gaze	no formal or informal mode
Adaptive Devices	bilateral hearing aids, corrective glasses	corrective glasses	none	polyurethane had splints

during intervention. Following baseline observations, each child was inverted for 9 minutes on an inversion board. Blood pressure was measured periodically to monitor possible adverse reactions to the intervention procedure. Positive effects of inversion were observed, as all 4 subjects demonstrated increased cumulative duration of head erect behavior during intervention (Figure 25). One subject appeared to maintain and generalize these gains while 3 subjects did not.

Integrated Summary

In the 2 studies completed utilizing inversion as the independent variable, the results suggest that the static method may be more effective for increasing head erect behavior. During the first study (Study 12) which employed a dynamic method of inversion, the measurement session was initially scheduled following the intervention. The intervention procedure consisted of rolling the subject in the prone position on a carpeted barrel from a starting point of 0 degrees to a point of inversion of 60 degrees from vertical. The subject was maintained in this inverted position for 30 seconds and then returned to the starting position. This procedure was repeated 12 times with a total cumulative duration of 6 minutes of inversion. During the intervention condition for the first subject, an additional measure for frequency and duration of head lifts was incorporated during the intervention session. We were concerned that the subjects might fatigue during intervention and that measurement at the end of the session would not reflect accurately the effects of this therapeutic technique. The results were mixed with two of the four subjects demonstrating an increase in the dependent variable. For one subject the increase occurred during intervention and for the other during the post-intervention measurement period.

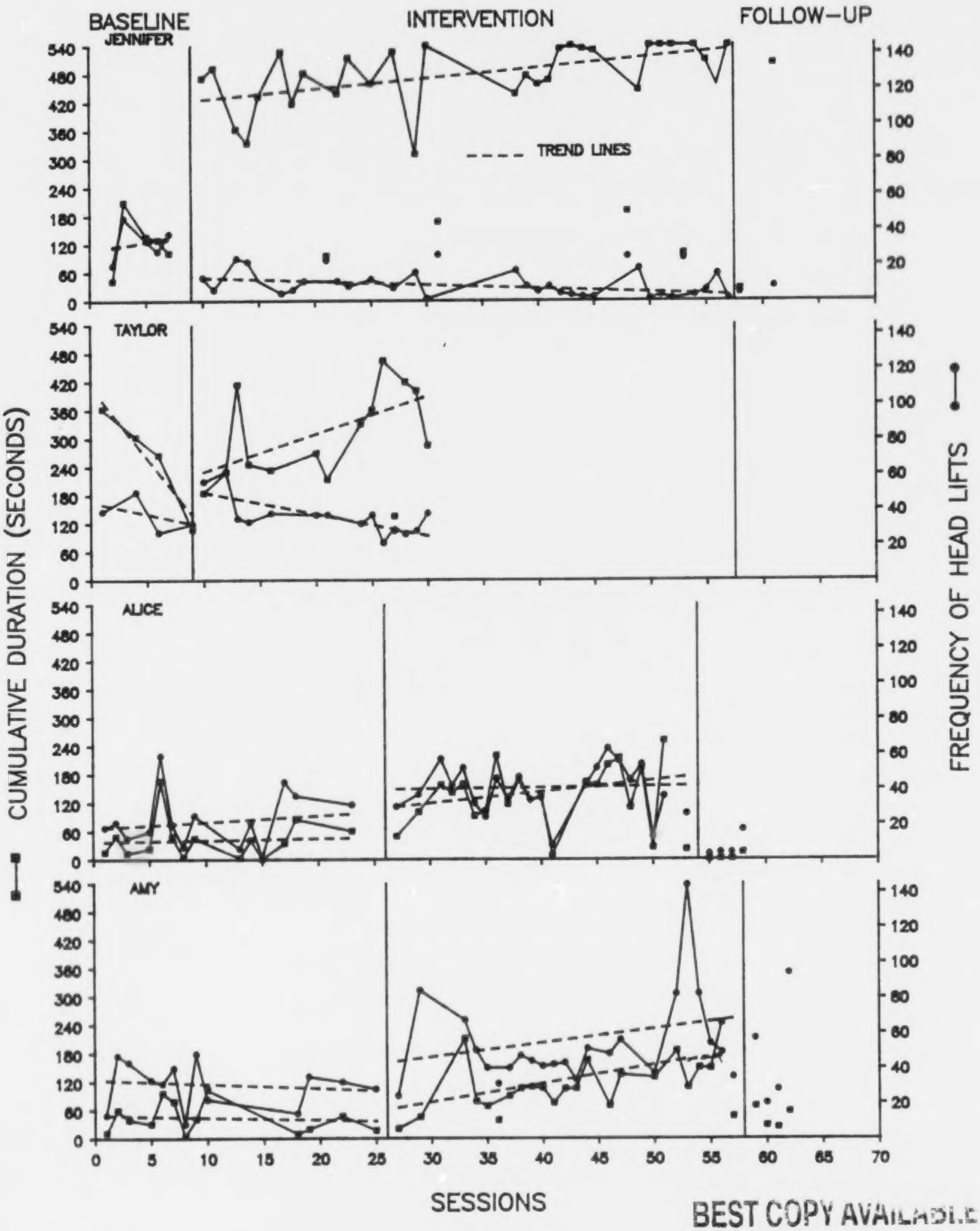

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Figure 25. Frequency of head lifts and cumulative duration for all subjects across conditions.

The second study utilized a static form of inversion. The methodology involved inverting the subject at an angle of 60 degrees from the vertical axis for a total duration of 9 minutes. Measurement occurred during intervention. All 4 subjects demonstrated increased cumulative duration of head erect during intervention.

Subject characteristics were analyzed across the 2 studies to determine if a differential effect fo age or type of motoric impairment emerged. The ages of the 6 youngsters who demonstrated an improvement in the dependent variable ranged from 1½ to 3½ years. The type of motoric impairment included: spasticity (4) and spastic-athetoid (2). Two of the 6 children were currently on medication for seizure control. For the 2 youngsters who demonstrated no discernible improvement, age was 3 years; one child presented with spasticity and one with spastic-athetoid movements. One of the 2 was on medication.

Although the small population makes generalizations difficult, it appeared that inversion like vestibular stimulation had a positive effect on children who presented with pyramidal and extrapyramidal symptoms.

Generalization and maintenance. Generalization and maintenance probes were conducted in the second study (Study 13). Although the results suggested that inversion was effective in increasing cumulative duration of head erect; maintenance, and generalization did not occur for 3 of the 4 subjects. Future research should investigate the effects of increasing the number of sessions per week or the overall length of the intervention on acquisition, maintenance and generalization. Similarly the optimal duration of inversion requires further investigation. Our data suggest that the inversion period should be at least 6 minutes as 3 of the 4 subjects demonstrated their maximal performance during the 3 to 6 minute interval.

Potential adverse reactions. A total of 8 subjects were involved in the 2 inversion studies. One subject was withdrawn from the second study during the intervention phase. This youngster was intermittently sick with otitis media and an upper respiratory infection. At approximately the 27th session she began exhibiting more frequent startle-like behaviors which her parents suspected may be associated with seizures. This included sudden crying, whining, and an increased startle reaction. An EEG taken during this interval did not demonstrate seizure activity. Four sessions later the child's physician recommended that the inversion be withheld for 2 weeks and she was subsequently withdrawn from the study upon her physician's request.

Data collected on the 3 children on seizure medication yielded 100% agreement on the nonoccurrence of seizures across studies. In addition, blood pressure was monitored across conditions on the 2 studies. A portable sphygmomanometer with an infant cuff and a Doppler instrument was used. All recordings fell in the normal range for each subject's chronological age.

Covariation probes. Data on covariation probes were collected across conditions in the 2 inversion studies. These data demonstrated no or only minimal change in behaviors which were functionally and developmentally related to the independent variable. Longitudinal research addressing the relationship between acquisition and emergence of potential covarying behaviors may better address this issue than our present studies designed to address basic effects.

Therapeutic Intervention Packages

Based on the results of the preceding studies, vestibular stimulation was selected as the independent variable for this final study. The dependent variables (i.e., reach and grasp) were selected from each subject's individual education plan. The behaviors were arranged developmentally and functionally in an individualized curriculum sequence. The project's developmental therapist and the classroom teacher developed a task analysis for each behavior. Following is a summary of the study.

Effects of vestibular stimulation on upper extremity movements: Study 14. An alternating treatment design across subjects was used to assess the effects of vestibular stimulation on upper extremity movements in preschoolers with multiple handicaps. This design was selected to determine if vestibular stimulation elicited an immediate effect on the dependent variables. Two children presenting with increased tone served as subjects (Table 19). Following baseline observations, the treatment condition (i.e., 6 minutes of vestibular stimulation) was randomly alternated with the no-treatment condition. Measurements of reach and grasp were collected across conditions in the children's classroom. For purposes of data analysis, the behavior descriptors for reach were contact and time for contact; grasp was also measured. Data from these descriptors reflect the most desired, controlled forms of reach-grasp behavior. Each session yielded scores for each upper extremity and a combined score for the right and left arms. Interobserver agreement for the dependent variables was acceptable across subjects. The results indicated an improvement in performance data for both subjects for several of the descriptors (Table 20). For the first subject contact for the right hand and both hands combined were greater during the treatment condition

Table 19

Characteristics of the Two Subjects in Study 14

Characteristics	Subjects	
	Alicia	Tiffany
Diagnosis	5 years 7 months	3 years 2 months
Diagnosis	Spastic quadriplegic cerebral palsy	cerebral palsy
Postural Tone	Increased tone in all extremities, neck and trunk	hypertonic extremities hypotonic neck and trunk
History of Services	At birth, none since	none
Gross Motor	5-6 months	6-8 months
Fine Motor	5-6 months	9-10 months
Cognitive	6-9 months	12 months
Mode of Communication	eye gaze	gestures, indescript utterances
Adaptive Devices	none	corrective glasses/ bilateral ankle-foot orthosis

Table 20

Mean Percent of Performance Scores Across Target Behaviors, Subjects and Conditions

	ALICIA			TIFFANY		
	baseline	tx	notx	baseline	tx	notx
Contact;						
left hand	20%	14%	20%	45%	40%	60%
right hand	19%	40%	27%	55%	56%	44%
combined	41%	64%	47%	100%	100%	100%
time for contact	121sec	158sec	142sec	66sec	39sec	37sec
grasp	0%	0%	17%	30%	50%	72%

than no treatment or baseline conditions. Performance data for latency (time for contact) demonstrated no appreciable differences across conditions. Data for grasp was increased during the no treatment condition as compared to the treatment or baseline conditions. For the second subject, performance data for contact, both for the right and left hands and both hands combined demonstrated no appreciable differences between baseline, treatment and no treatment conditions. There was a decrease in latency from baseline to treatment and this was maintained during the no treatment condition. Similarly there was an increase in grasp accuracy from baseline to treatment and continued in the no-treatment condition. The decrease in latency and increase in grasp accuracy occurred first in the treatment condition.

The results from this and previously reported studies suggest that vestibular stimulation may be a potential antecedent stimulus for a variety of motor programs. The generalized effect evidenced in the vestibular stimulation studies combined with the positive affective responses observed in subjects (i.e., increase in alertness, social responses, and vocalizations) indiate the need for additional research. Future research should continue to address the effect of this therapeutic technique on acquisition, generalization, and maintenance of a range of motor behaviors but also attempt to quantify its affect on subjects' biobehavioral state. It would be of great interest to determine if state is positively altered by vestibular stimulation with a subsequent correlation between biobehavioral state and acquisition of motor behavior.

DISSEMINATION

An important aim of this research program was to impact the education and treatment of young children with severe and multiple handicaps. Effective dissemination makes for better cost-benefit ratios for research dollars as well as education dollars. Coupled with sound research, it synergistically effects future research efforts also. Therefore, the results of these research studies have been presented in a form usable by the research community, and also educators and clinicians in the field. Following are a list of articles and regional and national presentations by project staff.

Articles

Kuharski, T., Rues, J., Cook, D., & Guess, D. (1985). Effects of vestibular stimulation on sitting behaviors among preschoolers with severe handicaps. *Journal of the Association for Persons with Severe Handicaps*, *10*, 137-145.

Cannon, S., Rues, J., Guess, D., & Melnick, M. Effects of therapeutic vibration on the acquisition of head erect behavior among preschoolers with severe handicaps. Accepted by *Physical Therapy*.

Rues, J., Kline, D., Cook, D., & Guess, D. Effects of inversion on head erect behavior among preschoolers with severe handicps. Submitted for publication.

Presentations

1983 - 1984 (Year 1, 3/1/83 - 2/28/84)

Rues, J. "Motor assessment and intervention with infants." Seminar presented at Comprehensive Assessment and Treatment of Children co-sponsored by Wisconsin Physical Therapy Association, Inc. and the Foundation for Physical Therapy, Marquette University, Milwaukee, Wisconsin, July, 1983. (250)

Rues, J. "Research strategies for evaluating therapeutic intervention techniques." Presentation to graduate SPED class, University of Kansas Medical Center, Kansas City, Kansas, November, 1984. (10)

Sheffey, A. "The effects of therapeutic vibration on the acquisition of upper extremity weight bearing in multiply handicapped preschoolers." Presentation at interdisciplinary staff meeting, Multiply Handicapped Preschool, University of Kansas Medical Center, Kansas City, Kansas, October, 1983. (10)

Kardinal, M. "The effect of variation on erect and symmetrical sitting in multiply handicapped preschoolers." Presentation at interdisciplinary staff meeting, United Cerebral Palsy Association, Kansas City, Missouri, November, 1983. (7)

Campbell, D. "The effect of vestibular stimulation on head erect behavior in multiply handicapped preschoolers." Presentation at interdisciplinary staff meeting, Regional Diagnostic Center, Kansas City, Missouri, August, 1983. (8)

Hasenbank, M. "The effect of vibratory stimulation on chewing behavior in multiply handicapped preschoolers." Presentation at interdisciplinary staff meeting, United Cerebral Palsy Association, Kansas City, Missouri, July, 1982. (8)

1984 - 1985 (Year 2, 3/1/84 - 2/28/85)

Guess, D., Rues, J., Cook, D., & Cannon, S. "Research on acquisition of motor skills in children with severe and multiple handicaps." Research Seminar, University of Kansas Medical Center, Kansas City, Kansas, December, 1984. (75)

Cook, D., & Westman, K. "Effects of vibration and vestibular stimulation on acquisition of motor skills." Presentation at Interdisciplinary Core Course, University of Kansas Medical Center, Kansas City, Kansas, October, 1984. (20)

Kloechner, J. "Effects of vibration on head erect behavior in multiply handicapped preschoolers." Presentation at interdisciplinary staff meeting, United Cerebral Palsy Association, Kansas City, Missouri, April, 1984. (5)

1985 - 1986 (Year 3, 3/1/85 - 2/28/86)

Guess, D., Rues, J., & Cook, D. "Effects of neurophysiological treatment techniques on motor skills in children with severe handicaps." Panel presentation at the Association for Persons with Severe Handicaps, Boston, Massachusetts, December, 1985. (60)

Rues, J. "Effects of neurophysiological treatment techniques on motor skills in children with severe handicaps." Poster presentation in National meeting of Occupational Therapists in Maternal and child Health, Santa Monica, California, January, 1986. (100)

Cook, D., & Westman, K. "Effects of neurophysiological treatment techniques on motor skills in children with severe handicaps." Presentation at American Occupational Therapy Association Annual Conference, Atlanta, Georgia, April, 1985. (150)

Rues, J. "Effects of vestibular stimulation on acquisition of sitting among preschool children with multiple handicaps." Presentation at Interdisciplinary Core Course, University of Kansas Medical Center, Kansas City, Kansas, November, 1985. (20)

Cook, D. "The effects of vestibular stimulation on head erect behavior in multiply handicapped preschoolers." Presentation to interdisciplinary staff at the Multiply Handicapped Preschool, University of Kansas Medical Center, Kansas City, Kansas, April, 1986. (6)

Cook, D. "The effects of vestibular stimulation on head erect behavior in multiply handicapped preschoolers." Presentation to interdisciplinary staff at United Cerebral Palsy Association, Kansas City, Missouri, May, 1986. (7)

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APPENDIX A

Quantitative Assessment Procedures for Measuring Head Erect Behavior

HEAD ERECT MEASUREMENT FOLLOWING ROTARY STIMULATION & VIBRATION

Materials and Equipment

Materials include a data sheet, stopwatches, pencils and a timing device.

Timing device. A cassette tape recorder and pre-recorded timing tape serve as the timing device. The timing tape marks off one minute intervals for a period of 3 minutes.

Data sheet. The data sheet includes space for recording the frequency of head lifts, frequency of arm position and the cumulative duration of head erect (Figure 1).

Positioning of the subject and observers

The subject is placed prone (on stomach) on the floor. The elbows are flexed and the hands placed on either side of the head. If the subject places his/her hands or fingers in the mouth, they are removed and repositioned at shoulder level on either side of the head. If the subject attempts to roll over, he/she is stopped and repositioned.

The examiner and optional second observer position themselves prone on the floor parallel to one another directly facing the infant. A distance of 18 inches separate the observer's face from that of the infant.

Measurement of the Head Erect

The following definitions are used in recording head erect behavior:

Head erect-prone position. The head is lifted or considered to be in the erect position when no part of the head or neck (chin to clavicle) are touching the supporting surface, nor resting on or touching the child's arms which are in contact with the supporting surface.

Head lift without arm support. The head is lifted and an elbow angle of less than 90° is present.

Head lift with forearm props. The head is lifted and an elbow angle greater than or equal to 90° is present.

Head lift with extended arm support. The head is lifted and no part of the arm is touching the supporting surface. Combinations of the above definitions are possible. One arm may fit one definition and the other arm may fit a different definition. These combinations are presented in the abbreviation code on the data sheet.

NAME:

BIRTHDATE:

DATE:

OBSERVER(S):

SETTING:

RELIABILITY:

Code: ↑ - no arm support

✓↑ - props on one forearm, other arm no support

✓✓ - props on forearms

✓| - props on one forearm and one extended arm

|| - props on extended arms

R - right arm

L - left arm

HEAD ERECT DESCRIPTORS				UPPER EXTREMITY WEIGHT BEARING DESCRIPTORS														
Head Turns	Head Lifts	Duration Longest Head Lift	Cumulative Duration: Head Erect or //	R	L	R	L	R	L	R	L	R	L	R	L	R	L	Reliability
				↑	↑	↑	✓	✓	↑	✓	✓	✓	|	|	✓	|	|	
Total																		

Figure 1. Data sheet for recording frequency of head lifts, cumulative duration of head erect and arm positions.

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Measurement. After the subject and observer/s are positioned, a 3-minute tape is started that marks off three time checks at 1-minute intervals. During the 3-minute session, simultaneous recordings of the following behaviors are made: frequency of head lifts, frequency of arm positions and cumulative duration of head erect.

Summation of the data. Scoring the trial involves summing the individual columns (i.e. head lifts, arm position) to determine the frequency of occurrence of each behavior. The cumulative duration of head erect is recorded from the cumulative stopwatch.

Interobserver agreement. Interobserver agreement for each session is determined by comparing the results of the observer to those of the examiner. Interobserver agreement for frequency of head lifts and arm positions is computed using the following formula:

$$\frac{\#\text{agreements}}{\text{disagreements \& agreements}} \times 100 = R \text{ (overall agreement)}$$

Interobserver agreement for cumulative duration of head erect is computed by dividing the smaller number of seconds by the larger number of seconds and multiplying the quotient by 100.

HEAD ERECT MEASUREMENT DURING INVERSION

Materials and Equipment

Materials include a data sheet, stopwatches and a timing device.

Timing device. A cassette tape recorder and pre-recorded timing tape serve as the timing device. The timing tape marks off 3-minute intervals for a period of 9 minutes.

Data sheet. The data sheet includes divisions for frequency of head lifts, cumulative duration and possible side effects. (see Figure 1).

Positioning of the Subject and Observers

The child is placed in the horizontal or inverted position on the inversion board as described in Appendix B. The examiner and optional observer position themselves at a vantage point so that head erect behavior can be measured. A distance of 12-18 inches separates the observer's face from that of the child.

Measurement of Head Erect

The head is lifted or considered to be in the erect position when no part of the head or neck (chin to clavicle) is touching the supporting surface, nor resting on or touching the child's arms which are in contact with the supporting surface.

Measurement. After the subject and observer(s) are positioned, a 9-minute tape is started that marks off 3 time checks at 3-minute intervals. Frequency of head lifts and cumulative duration of head erect are recorded for each 3-minute interval along with the occurrence/non-occurrence of potential side effects.

Summation of the data. Scoring the session involves summing the 3-minute totals for both frequency of head lifts and cumulative duration of head erect.

Interobserver agreement. Interobserver agreement for each session is determined by comparing the results of the observer to those of the examiner. Interobserver agreement for frequency of head lifts is computed using the following formula:

$$\frac{\text{\#agreements}}{\text{\#disagreement \& agreements}} \times 100 = R \text{ (overall agreement)}$$

Interobserver agreement for cumulative duration of head erect is computed by dividing the smaller number of seconds by the larger number of seconds and multiplying the quotient by 100.

Effects of Inversion On Head Erect
Data Sheet

Name: Date: Level: pre(+/-)_

Observer: Session No.: post(+/-)_

Time	Head Lifts (frequency)	Cumulative Duration (seconds)	Side Effects y=yawning f=facial flushing c=crying p=perspiration v=vocalizing	Seizur
3 min.				
Total				
6 min.				
Total				
9 min.				
Total				
Overall Total				
Overall Rate				
Overall % for rel.				

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Blood Pressure: pre____ post____

Figure 1. Data sheet for recording frequency of head lifts, cumulative duration of head erect, blood pressure and affective responses.

APPENDIX B

Quantitative Assessment Procedure for Measuring Sitting

ERECT SITTING MEASUREMENT

Materials and Equipment

The materials and equipment used for the assessment of erect sitting include a plexiglass section device, a timing device, data sheets, a 14.6 cm high bolster, an adhesive marker, and pencils. Specifications for each piece of equipment are listed below:

Plexiglass section device. A 60 cm high and 90 cm wide clear plexiglass sheet is used. The plexiglass sheet is mounted on a wooden frame for support. Alternating strips of red and black adhesive tape divide the plexiglass sheet into six equal sections of 15° each. The sections are numbered one through six consecutively with each section encompassing successive 15° angles from the vertical plane (Figure 1).

Timing device. A cassette tape recorder and pre-recorded timing tape serve as the timing device. The timing tape marks off 5-second intervals for a period of three minutes, resulting in 36 time checks.

Data sheets. The data sheet includes space for recording data at 5-second intervals for each of the six grid sections designated on the plexiglass device. A column for position checks (e.g., tailor, propped, etc.), and a column to note if the subject is repositioned, are also included. A sample data sheet is shown in Figure 2.

Adhesive marker. A 12.7 mm adhesive star is placed on the subject's shoulder (below the acromion process and centered over the deltoid muscle) as a reference point.

Positioning of the Subject and Observers

The position selected for each subject is determined by observation of the most stable sitting posture. The potential sitting positions and descriptions are found in Figure 3.

After the subject's upper clothing are removed, a 12.7 mm adhesive star is placed on the subject's shoulder (e.g., 2.54 cm below the acromion process and centered over the deltoid muscle). The subject is then positioned behind the section device so that his/her left side is toward the grid and his/her hip joint is in alignment with the bottom corner of the plexiglass at the common origin of the angles. An assistant is positioned behind the subject to prevent falling.

The examiner and observer are positioned prone at a distance of 2.4 m from the plexiglass section device so that they view the subject through the device. The examiner is supported under her chest with a 14.6 cm high bolster. The observer rests his/her chin on the examiner's shoulder thus making the discre-

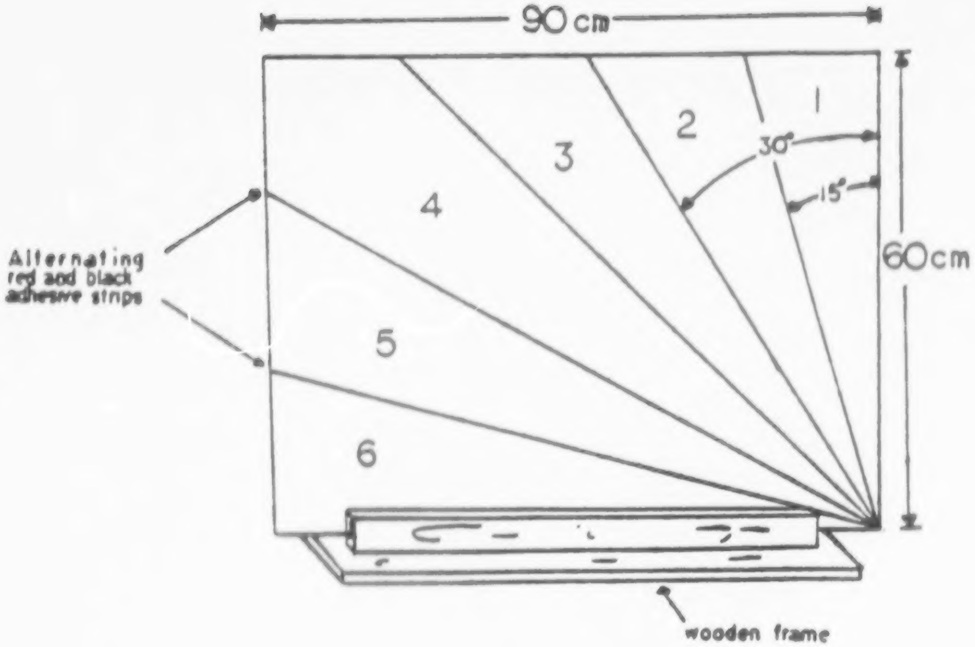

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Figure 1. Plexiglass suction device for measuring erect sitting.

TIME: ________

STABILITY IN SITTING

SUBJECT: ________________

OBSERVER: ________________________

DATE: ________________________

SEATING EQUIPMENT: ____________

SESSION NUMBER: ________

SITE: ________________________

RECORD POSITION EVERY 30 SECONDS WITH ONE DESCRIPTOR FROM EACH CATEGORY

(I)	(II)	(III)
L-LONG	S-SUPPORTED	P-PROPPED
T - TAILOR	I-INDEPENDENT	N-NOT PROPPED
R - RING		

*INDICATE REPOSITIONING BY MARKING STAR(*)IN THE ASSIST SPACE

Time	1	2	3	4	5	6	Rel.	Pcs.	Ass.
:05									
:10									
:15									
:20									
:25									
:30									
:35									
:40									
:45									
:50									
:55									
1:00									
1:05									
1:10									
1:15									
1:20									
1:25									
1:30									
1:35									
1:40									
1:45									
1:50									
1:55									
2:00									
2:05									
2:10									
2:15									
2:20									
2:25									
2:30									
2:35									
2:40									
2:45									
2:50									
2:55									
3:00									
Total									

RELIABILITY: ____ out of ___ TRIALS = ____%

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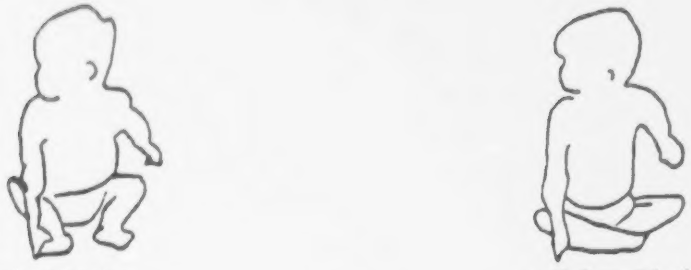
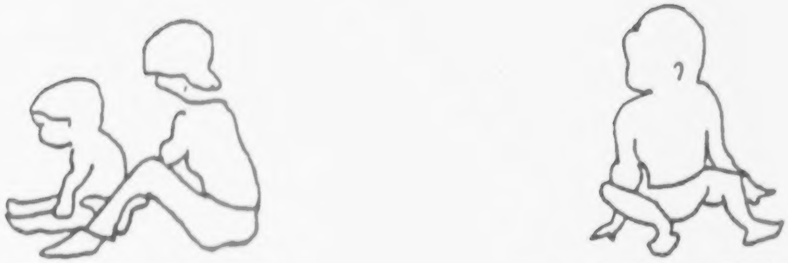
Figure 2. Data sheet for recording erect sitting.



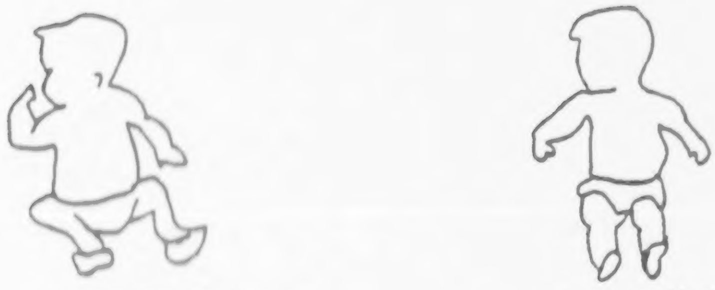
a. Ring Sitting
Legs form a circle

b. Tailor Sitting
Legs are crossed



c. Supported Sitting
held at pelvis

d. Propped Sitting
body weight on hands
or elbows



e. Independent Sitting
no weight on hands and
no support at pelvis

f. Long Sitting
legs with extended
knees

Figure 3. Potential sitting positions.

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pancy in the angles of observation minimal, so the angle of the subject's spine in relation to the vertical position can be reliably measured with the section device. A tape recorder with the timing tape is positioned within reach of the observers. The arrangement of the plexiglass section device, the subject and assistant, and the examiner and observer is illustrated in Figure 4.

Measurement of Sitting

The subject's back posture in relation to the trunk's deviation from the vertical plane, as viewed from the side, is used to record erect sitting.

Measurement. After the subject and observers are positioned, a 3-minute tape is started that marks off 36 time checks at 5-second intervals. The numbered section (1 through 6) in which the adhesive marker on the subject's shoulder is observed is recorded at each time check. If the marker is directly on a line, it is judged to be in the section directly above that line. If more of the star is visible below the line, it is judged to be in the section below. If the subject leans backward so the marker is off the plexiglass (illustrated in Figure 5), a line is drawn through that time-check on the data sheet. If the subject begins to fall out of the sitting position, the assistant repositions the subject into erect sitting and a slash is placed in that time-check, as well as recording a star in the repositioned column on the data sheet.

Summation of the data. For purposes of data analysis, erect sitting is identified as sitting in a position within either section 1 or section 2. The percentage of erect sitting is computed by dividing the total number of occurrences in which the subject is observed in sections 1 and 2 by the total number of time checks for which data is recorded. This is converted into the percentage of erect sitting. For example:

	Sections					
	1	2	3	4	5	6
Totals	13	5	13	3	0	0

(in a total of 34 time-checks scored)

Use the following equation:

$$\frac{\text{\# of occurrences of (section 1 + section 2)}}{\text{\# of time checks scored}} \times 100 = \text{percentage of erect sitting}$$

Therefore,

$$\frac{\text{18 (sections 1 \& 2)}}{\text{34 time checks}} \times 100 = \text{53\% of erect sitting}$$

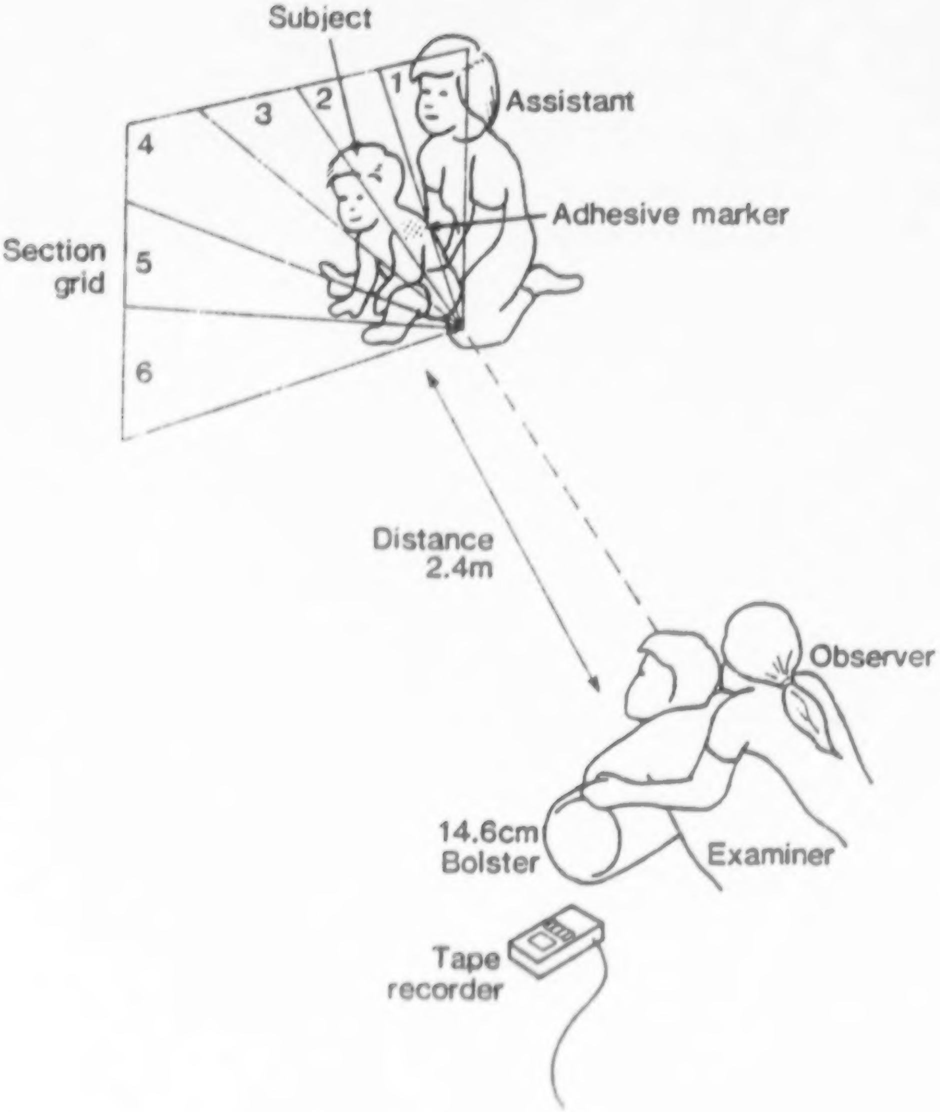

Figure 4. Positioning of subject and observers for recording erect sitting.

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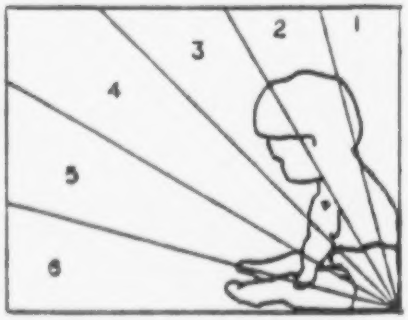
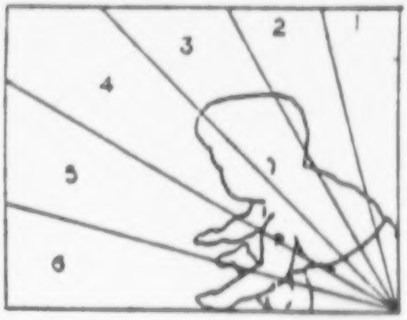
a) Sitting in section 3.



b) Sitting in section 4.



c) Sitting in position "off" the grid.

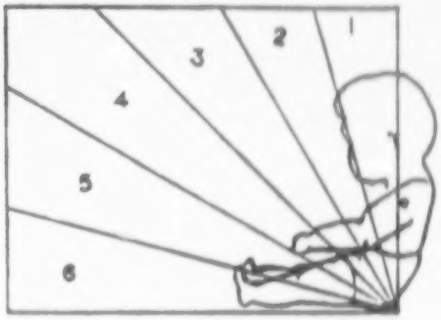


Figure 5. Shoulder marker as viewed through different sections of the plexiglass grid.

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Interobserver Agreement

Interobserver agreement for each trial is determined by comparing the results of the observer to those of the examiner. The interobserver agreement is calculated as follows:

$$\frac{\text{\# of agreements}}{\text{\# of disagreements \& agreements}} \times 100 = R \text{ (overall agreement)}$$

Agreement for each trial is computed using the formula above. Agreement of 80% or better is considered to be acceptable.

Visual alignment of the observers is checked prior to each measurement of erect sitting by verbally comparing each observer's recording of the position of a 12.7 mm star that is slowly moved through the sections behind the plexiglass grid by the assistant.

Observers are trained to a minimum criteria of 80% agreement with the investigator prior to conducting reliability checks for the measure of erect sitting.